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DEVELOPMENT OF AN INTEGRATED PACKAGE OF PHYSICS MODELS FOR SCENE SIMULATION STUDIES TO SUPPORT SMART WEAPONS STUDIES

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The Balanced Technology Initiative (BTI) on Smart Weapons Operability Enhancement (SWOE) has as a goal to model the radiant field from complex natural backgrounds. During the three years of the program, the calculation of these radiant fields has evolved to produce a process, known as the SWOE Process, that will enable a smart weapons designer or tester to specify and obtain the data required to describe the physical characteristics and the environmental conditions of a scene, model the physical processes controlling the generation of the radiant field, and display and analyze the results of the simulated scene.

In this, the last year of the BTI/SWOE program, the emphasis was on the delivery of a package of models on a computer platform for use in performing scene simulations for smart weapons design and testing applications. The efforts reported on here consisted of making enhancements to the SWOE thermal models and the design of a new Command Interface System and User Interface System.

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DEVELOPMENT OF AN INTEGRATED PACKAGE OF PHYSICS MODELS FOR SCENE SIMULATION STUDIES TO SUPPORT SMART WEAPONS DESIGN STUDIES

1 INTRODUCTION

1.1 Background and Purpose of Research

The Balanced Technology Initiative (BTI) on Smart Weapons Operability Enhancement (SWOE) has as a goal to model the radiant field from complex natural backgrounds. During the three years of the program, the calculation of these radiant fields has evolved to produce a process, known as the SWOE Process, that will enable a smart weapons designer or tester to:

- Obtain and specify the data required to describe the physical characteristics and the environmental conditions of a scene
- Model the physical processes controlling the generation of the radiant field
- Display and analyze the results of the simulated scene.

SPARTA has had responsibility for the development and integration of the SWOE thermal models into the SWOE Process. During the second year of the program, an Interim Thermal Model (ITM) and 3-D thermal model for individual trees were developed and delivered that permitted one to produce the temperature

fields driving the radiant fields in a passive infrared simulation.[1,2] In addition, a preliminary version of a Command Interface System (CIS) was developed to serve as a prototype.

In this, the last year of the BTI/SWOE program, the emphasis was on the delivery of a package of models on a single computer platform for use in performing scene simulations for smart weapons design and testing applications. SPARTA's efforts in this regard consisted of making enhancements to the SWOE thermal models and the design of a new Command Interface System and User Interface System.

The ITM design enhancements consisted of a number of tasks. One task involved the redesign and consolidation of the databases required to run the SWOE physics models. A second involved enhancements to the 1-D thermal response model for surfaces and TREETHERM, the 3-D thermal model for trees. A third involved the development and integration of a preliminary atmospheric radiation package for the SWOE program. The final effort involved the development of a new, machine independent User Interface System and controlling Command Interface System. The purpose of this report is to describe the work performed by SPARTA to fulfill those tasks.

1.2 Organization of Report

Chapter 2 provides an overview of the models that make up the SWOE system. Chapter 3 describes how the databases used by the SWOE physics models were redesigned and structured while Chapter 4 describes the changes and enhancements made to the SWOE thermal models. Chapter 5 discusses the SWOE Interim Atmospheric Radiative Transfer Package (IARTP) that was developed. Chapter 6 presents a discussion of and User's Guide for the SWOE User Interface System and Command Interface System. Chapter 7 presents a summary and recommendations for future upgrades to the SWOE system. Finally, three Appendices are included listing the environmental data included with the system, giving the procedures required to add data to the system, and describing the program drivers used to run the SWOE models, respectively.

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1 Hummel, J.R., Longtin, D.R., Paul, N.L., and Jones, J.R. (1991) "Development of the Smart Weapons Operability Enhancement Interim Thermal Model," Phillips Laboratory, Hanscom AFB, Massachusetts, PL-TR-91-2073, ADA 238995.

2 Hummel, J.R., Jones, J.R., Longtin, D.R., and Paul, N.L. (1991) "Development of a 3-D Tree Thermal Response Model for Energy Budget and Scene Simulation Studies," Phillips Laboratory, Hanscom AFB, Massachusetts, PL-TR-91-2108, ADA 240693.

2 OVERVIEW OF THE SWOE MODELS

The SWOE system is designed as a tool for smart weapons testers/designers to use in understanding the performance of present and future Electro-Optical (EO) sensors. The SWOE package of models will allow the user community to test sensor concepts for realistic environmental conditions. It is hoped that this capability will lead to considerable savings in development costs and shorten the time required to go from the drawing board to the production line. Figure 1 gives a schematic overview of the SWOE system.

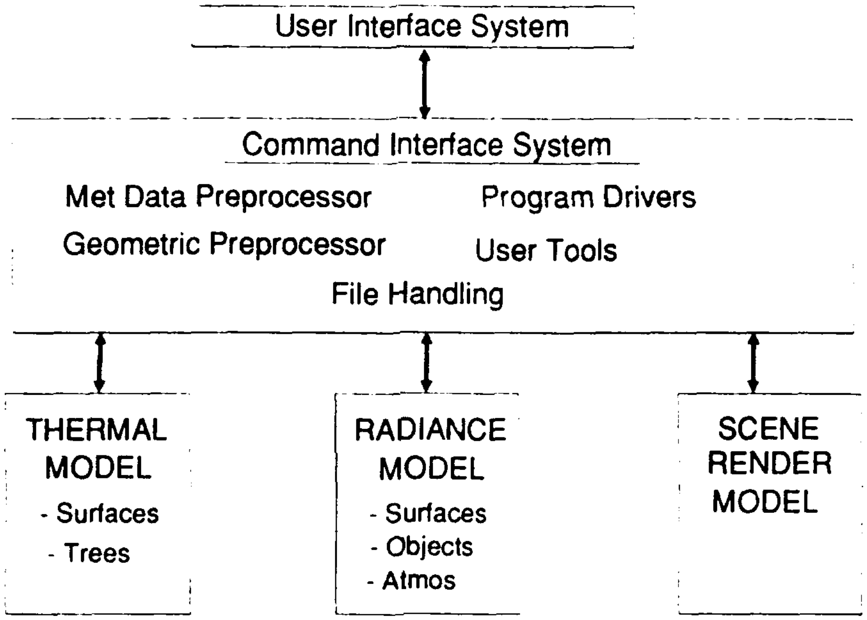

Figure 1. Overview of the SWOE Simulation System

The SWOE User Interface System (UIS) allows the user to specify the conditions for a given SWOE simulation system. These user-supplied inputs, which are described later in this report, are used by the SWOE Command Interface System (CIS) to determine what databases must be accessed to provide the environmental data and terrain information required for the various physics models. The CIS schedules the execution of the physics modules, providing the user with the opportunity to review output products as the simulation progresses.

In the subsections to follow, a brief discussion is presented on the SWOE physics models. The discussion is only intended as an overview and the interested reader is referred to the detailed technical reports for more detailed information about the models.

2.1 SWOE Thermal Models

The SWOE Thermal Models are used to calculate the surface temperatures for a wide variety of surfaces, including vegetated and non- vegetated surfaces, bodies of water, and snow/ice- covered surfaces. The models can be used for any season.

The thermal models are driven by conventional weather data, such as standard surface weather observations and radiosonde data. Default databases of seasonally dependent thermal properties are provided to cover a set of standard surfaces that are commonly encountered in scene simulation.

The thermal models also account for the effects of vegetation. SWOETHRM, the thermal model for surfaces, includes the effects of simple vegetation, such as grasses and crops, and extended forest canopies. TREETHERM, a 3-D thermal model, calculates temperatures for individual trees with and without leaves.[2] Two geometric representations of trees, based on measurements of actual trees, have been included with the SWOE package and can be used to calculate the temperature fields for trees in a scene simulation.

The SWOE Thermal Models are driven by the incoming solar radiation field and the infrared radiation from the atmosphere. The atmospheric radiation budget is calculated using a modified version of LOWTRAN7,[3] one of the standard atmospheric radiance and transmission codes used by the DoD community.

2.2 SWOE Radiance Models

The SWOE Radiance Models consist of a set of models that are used to calculate the radiance from elements in the scene as well as to calculate the position of shadows in the scene.[4] The SWOE radiance calculations are performed using two parallel computational paths, one for terrain and one for 3-D objects. The terrain radiance calculations are performed with a new model, the Improved Background Radiance Model (IBRM).[5] Radiances for 3-D objects are computed with a module from the SPIRITS code,[6] a U.S. Government standard for calculating radiances from aircraft. Both radiance models include important phenomenology such as spectrally varying directional emissivities and bidirectional reflectivities, spectral

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[3] Kneizys, F.X., Shettle, E.P., Abreu, L.W. Chetwynd, J.H., Anderson, G.P., Gallery, W.O., Selby, J.E.A., and Clough, S.A. (1988) "Users Guide to LOWTRAN7," Air Force Geophysics Laboratory, Hanscom AFB, Massachusetts, AFGL-TR-88-0177, ADA 206773.

[4] Conant, J.A., and Hummel, J.R. (1991) "Thermal and Radiometric Modeling of Terrain Backgrounds," SPIE Proceedings of Characterization, Propagation, and Simulation of Sources and Backgrounds, Vol. 1486, 217-230.

[5] Conant, J. and DeAnelis, J. (1992) "IBRM User's Manual," Aerodyne Research, Inc., Billerica, Massachusetts, (In progress)

[6] Aerodyne Research (1991) "SPIRITS, Hardbody User's Manual," Aerodyne Research, Inc., Billerica, Massachusetts, ARI-RR- 877, September.

atmospheric transmission and radiances along a viewing path, and radiance sources from the atmosphere, sun, and adjacent scene elements.

The terrain in a scene is modeled with a set of textured polygons which overlay the topographic grid. The polygon definitions and geometry are determined from data contained in the SWOE databases. The radiances calculated for each polygon are based on the surface temperatures produced by the SWOE thermal models.

2.3 SWOE Cloud Models

Clouds are one of the more important modulators of the surface energy balance. The SWOE cloud model package considers the influence of clouds for both the solar and infrared fluxes. During the thermal loading phase of the surface temperature calculation, also known as model spin-up, a simple model is used to modulate the broadband downwelling flux in the solar and infrared regions. The impact of clouds is accounted for using the standard cloud data contained in surface weather observation reports. During this phase of the calculation, one is not concerned with the actual location of cloud shadows in the scene. At the time of simulation, however, one must take into account the position of cloud shadows. Although the cloud generation models are not shown in Figure 1, they are an important part of the simulation process.

Two cloud models are used in the SWOE package. One model generates the vertical positions of the clouds and a second one positions the clouds in 3-D for projection of the cloud shadows. Clouds are generated by the Cloud Scene Simulation Model (CSSM).[7] The CSSM uses a Successive Random Additions (SRA) fractal algorithm to generate the horizontal distribution of the clouds based on the cloud amount and type. Separate 1-D and 2-D SRA algorithms are used to generate the upper and lower surface of the cloud, while a 3-D SRA algorithm is used to modulate the liquid water density (LWD) information at each cloud grid point in the cloud volume. The mean LWD information as a function of cloud type and altitude has been obtained from an extensive cloud database.[7] Cloud shadows are generated using a post processor that employs a ray tracing techniques, the spatial cloud distribution produced by CSSM, and the solar zenith and azimuth angles (or latitude, longtiude, month, day, and time.)

[7] Cianciolo, M.E., Hersh, J.S., and Ramos-Johnson, M.P. (1991) "Cloud Scene Simulation Modeling, Interim Technical Report," The Applied Sciences Corporation, Reading, Massachusetts, TR-6042-1.

3 REDESIGN OF THE SWOE PHYSICS DATA FILES

The databases used in the SWOE Interim Thermal Model[1] (ITM) were, to a large extent, intimidating to the user. The databases contained a number of parameters that were either difficult to obtain from conventional resources or were only used if one was performing detailed, research grade sensitivity studies. (Throughout this report, "research grade" studies will be meant to imply the detailed study of physical processes from a single type of terrain.) In order to simplify the use of the SWOE physics models, a redesign of the databases has been performed. Parameters that are typically only used for detailed sensitivity studies have been assembled into a "research grade" database, while others have been "hardwired" into the models, forming a built-in data library that can be used to cover the typical range of SWOE scenarios. The purpose of this discussion is to describe the database redesign effort.

There were two goals for the database redesign effort. First, to simplify the use of the SWOE models by removing the requirement to specify a lot of information that the user would typically not change. The secondary goal was to fill in some gaps in the databases such as the inclusion of seasonally dependent values.

The resulting redesigned SWOE databases are schematically represented in Figure 2. The data that describe the types of terrain being modelled are collected and stored as Feature Identification Data.[8] These data consist of the different land use categories and the slope and aspect data. It is assumed that these data are prepared offline from the SWOE system and provided as input. Also contained under this category are the types and locations of objects, such as trees or targets. Next is the environmental databases, which in the case of the package being delivered, is a seasonal database of environmental data for the Ft. Hunter-Liggett, California area. Finally, there is the built-in library of data required for the thermal models.

3.1 Required Environmental Data

A review of the environmental data requirements for the SWOE Thermal, Radiance, Cloud, and Atmospheric Radiation models was made to determine what parameters are required by the models and what commonalities exist. When compared to the previous database requirements,[1] five variables have been either eliminated or hardwired into the models. (The three shelter heights have been eliminated and an assumed height of 2 m has been hardwired into SWOETHRM. The scene average surface albedo is no longer required at all. Finally, the precipitation grain size (required when snow is present) has been hardwired into the default database for winter conditions.)

[8] Kress, R. (1992) "Description of the SWOE Terrain Data," US Engineer Waterways Experiment Station, Vicksburg, MS. (in process.)

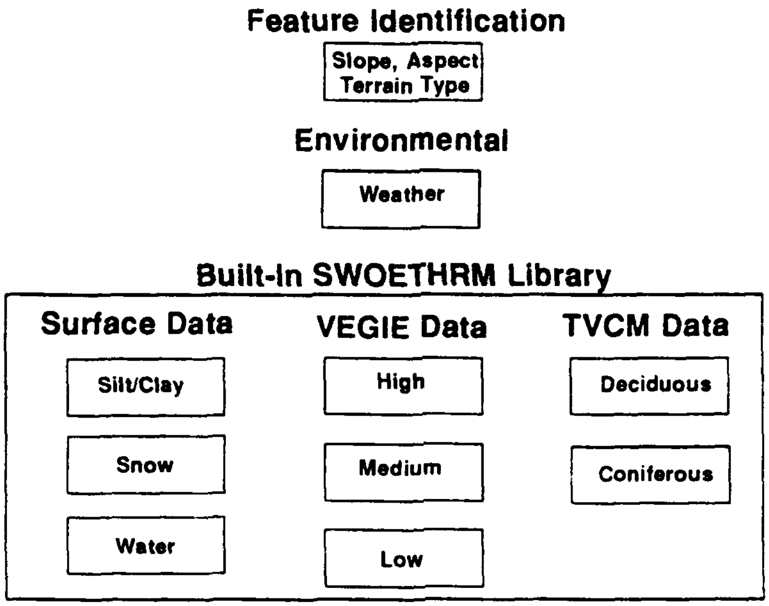

Figure 2. Schematic Representation of the Redesigned SWOE Databases

Table 1 contains the list of the environmental variables required for the SWOE Thermal, Radiance, and Atmospheric Radiation models. Table 1 (a.) contains the list of required environmental data that are based on conventional surface weather observations and Table 1 (b.) contains the cloud parameters required by the SWOE physics models. The Tables also list the units required, the format, and the source of the data within the SWOE concept, *i.e.* resident in the SWOE databases, hardwired, or supplied by the user.

3.1.1 Basic Environmental Data

Four new variables have been added to the list of required environmental data: a seasonal flag, a boundary layer aerosol type, solar zenith angle, and solar azimuth angle. The seasonal flag is an integer index that is used to characterize the season. The values used are 1 = winter, 2 = spring, 3 = summer, and 4 = fall. This is being used because seasonally dependent data are now incorporated into the environmental databases and vegetative parameters. The boundary layer aerosol type is required for the atmospheric radiation and radiance models. The range of boundary aerosol types currently included is listed for reference. (Note that two of the standard LOWTRAN7[3] aerosols, the Navy Maritime Aerosol and the User Defined Aerosols are not included because they require additional inputs that are not easily obtainable on a routine basis. It is recommended that at some point an option to include user-defined aerosols be implemented in the SWOE process.)

Table 1. Meteorological Variables Required by the SWOE Physics Models. (a.) Basic Environmental Data

DESCRIPTION OF VARIABLE	UNITS	DESIRED SOURCE
Descriptive Title of Met Data Set		Data Base
Reporting Station Altitude Above Sea Level	m	Data Base
Reporting Station Latitude (+ Positive North)	deg	Data Base
Reporting Station Longitude (+ West)	deg	Data Base
# Time Zones From Greenwich		Data Base
Seasonal Index (1, 2, 3, or 4)		Data Base
Boundary Layer Aerosol Type (0 - 10)		Data Base
0 = No Aerosols		
1 = Rural, 23 km visibility		
2 = Rural, 5 km visibility		
3 = (Currently Not Used)		
4 = Maritime, 23 km visibility		
5 = Urban, 5 km visibility		
6 = Tropospheric, 50 km visibility		
7 = (Not Used)		
8 = Advective Fog		
9 = Radiative Fog		
10 = Desert Aerosols		
Time Interval of Met Data	hr	Data Base
# Lines of Met Data		Data Base
Year of Met Data		Data Base
Julian Day		Data Base
Local Hour		Data Base
Minutes		Data Base
Surface Pressure	mb	Data Base
Surface Temperature	C	Data Base
Surface Relative Humidity	%	Data Base
Surface Wind Speed	m/s	Data Base
Surface Wind Direction	deg	Data Base
Surface Visibility	km	Data Base
Precipitation Rate	mm/hr	Data Base
Precipitation Type (0, 1, or 2)		Data Base
0 = None		
1 = Rain		
2 = Snow or Sleet		
Total Global Solar Flux	watts/m^2	Data Base[1]
Direct Solar Flux	watts/m^2	Data Base[1]
Diffuse Solar Flux	watts/m^2	Data Base[1]
Downwelling Infrared Flux	watts/m^2	Data Base[1]
Solar Zenith Angle	deg	Calculated
Solar Azimuth Angle	deg	Calculated

[1] If Not Included in the Database, Values Are Calculated by the Atmospheric Radiation Model and Added to the Data File During Processing by the SWOE Command Interface System

It is noted that the aerosol index is not a regular surface weather observable. Instead, the index is being based on the broad aerosol categories as used in LOWTRAN 7.[3] For the specific Hunter-Liggett database that is being assembled, the "Rural, 23 km visibility" aerosol category (IHAZE = 1 in the LOWTRAN nomenclature) is being used for the majority of the situations. Note that the visibility data, when included in the surface weather data files, overrides the 23 km visibility in the LOWTRAN calculations.)

3.1.2 Cloud Data

Table 1 (b.) contains the list of cloud parameters required by the SWOE physics models. The majority of these parameters are required by the SWOE cloud structure and shadow models.[7] In reviewing the list, one notes that many of the required cloud parameters are non standard data or specific to the models being used. As a result, a number of assumptions have been made to simplify the cloud data requirements.

3.1.3 Structure for Surface Environmental Data

Table 2 contains the structure for the surface environmental data delivered with the SWOE models. Note that Line 6 is repeated for each time period.

The SWOE thermal models require solar and infrared flux data, but it is recognized that these data may not always be available. Therefore, prior to performing a calculation, the Command Interface System checks to see if flux data exist in the environmental database. If they do not, the SWOE atmospheric radiation package is used to calculate the data and add them to the data bases. (The reader is referred to Section 4.3 for a discussion of the SWOE Atmospheric Radiation Package.)

Weather data for Fort Hunter-Liggett have been assembled on a seasonal basis. Data for each season have been collected over a seven day period. The data were taken over a three year period and assembled for use in SWOE. Table 3 includes a summary of the weather in the data files that comprise the Hunter-Liggett surface weather data files. The Table lists the Julian day of each day of data, when the data were actually collected, and a summary of the weather for the day. Figure 3 contains a sample listing of the surface weather data collected for Hunter-Liggett. Appendix A contains a listing of all of the surface weather data.

In assembling the environmental database, it was discovered that not all of the required data were provided or were not provided for all time periods. As a result, a set of executive decisions were required to fill in the gaps.

Visibilities and precipitation were not always reported on a twenty-four hour basis or, in some cases, were absent altogether. When this occurred, values were added to the database based on any apparent trends that were present and a "common sense" interpretation of the overall weather data.

Table 1. (Cont.) (b.) Cloud Data Required by the SWOE Atmospheric Radiation and Cloud Models

DESCRIPTION OF VARIABLE	UNITS	DESIRED SOURCE
SWOE Atmospheric Radiation Model		
Cloud Type of Each Layer		Data Base
Cloud Amount for Each Layer	%	Data Base
Cloud Height Base and Thickness of Cirrus Clouds	km	Data Base
Cloud Structure Model		
Index Describing Cloud Structure Model (1 or 2)		User
1 = Fractal Browning Motion		
2 = Boehm Sawtooth		
Number of Cloud Layers (1, 2, or 3)		Data Base
Fractional Cloud Cover for Each Layer	%	Data Base
Cloud Type (0 - 7)		
0 = No Clouds		
1 = Stratus		
2 = Stratocumulus		
3 = Nimbostratus		
4 = Altostratus		
5 = Cirrus		
6 = Cirrostratus		
7 = Cirrocumulus		
Cloud Base Height Above Ground	km	Data Base
Low Clouds: 0 - 3 km		
Middle Clouds: 3 - 6 km		
High Clouds: 4 - 20 km		
Cloud Top Height Above Ground	km	Data Base
Low Clouds: 1 - 4 km		
Middle Clouds: 4 - 8 km		
High Clouds: 6 - 20 km		
Horizontal Range in x, y	km	User
Horizontal Resolution	km	User
Vertical Resolution	km	User
Surface Temperature	C	Data Base
Random # Seed		CIS
Name of Output File		User/CIS
Cloud Shadow Model		
Name of Output File With Cloud Structure		User/CIS
Name of Final Output File		Data Base
Size of Scene Domain in x, y	km	User
Resolution in x, y	km	User
Index for Source of Solar Zenith and Azimuth Angles		Data Base
1 = Enter Values		
2 = Enter Time and Location Data		

Table 2. Format of the Surface Meteorological Data. Note that line # 6 is repeated for each time period of data

LINE #	DESCRIPTION OF VARIABLE	UNITS	DATA TYPE*
1	Descriptive Title of Met Data Set		C
2	Station Altitude Above Sea Level	m	R
	Station Latitude (+ Positive North)	deg	R
	Station Longitude (+ West)	deg	R
	# Time Zones From Greenwich		I
3	Time Interval of Met Data	hr	R
	# Lines of Met Data		I
	Year of Met Data		I
	Seasonal Flag		I
	(1 = Winter, 2 = Spring, 3 = Summer, 4 = Fall)		
4	Tabular Header Material for Met Data		
5	Tabular Header Material for Met Data		
6	Julian Day		I
	Local Hour		I
	Minutes		I
	Surface Pressure	mb	R
	Surface Temperature	C	R
	Surface Relative Humidity	%	R
	Surface Wind Speed	m/s	R
	Surface Wind Direction	deg	R
	Surface Visibility	km	R
	Boundary Layer Aerosol Type		I
	Precipitation Rate	mm/hr	R
	Precipitation Type		I
	Fractional Low Cloud Amount		R
	Low Cloud Type		I
	Fractional Middle Cloud Amount		R
	Middle Cloud Type		I
	Fractional High Cloud Cover Amount		R
	High Cloud Type		I
	Total Global Solar Flux	watts/m^2	R
	Direct Solar Flux	watts/m^2	R
	Diffuse Solar Flux	watts/m^2	R
	Downwelling Infrared Flux	watts/m^2	R
	Solar Zenith Angle	deg	R
	Solar Azimuth Angle	deg	R

* C - Character R - Real I - Integer

Table 3. Summary of Weather Conditions in the Fort Hunter-Liggett Surface Weather Data Files

JULIAN DAY	DATE DATA TAKEN	SEASON	COMMENTS
7	7 Jan 1990	Winter	Clear Skies, Visibilities Missing
8	8 Jan 1990	Winter	Clouds 0600 - 1600 LST
9	9 Jan 1990	Winter	Fog 0600 - 0900 LST, Some Visibilities Missing
10	10 Jan 1990	Winter	Clouds 0600 - 1600 LST
11	11 Jan 1990	Winter	Overcast 0500 - 1600 LST
12	12 Jan 1990	Winter	Cloudy Skies 0600 - 1600 LST, Precipitation 0300 - 1800 LST, Some Visibilities Missing
13	13 Jan 1990	Winter	Precipitation Reported, No Clouds Reported, Visibilities Missing
101	10 April 1988	Spring	Clear Skies, Visibilities Missing
102	11 April 1988	Spring	Clouds 0500 - 1400 LST
103	12 April 1988	Spring	Clouds 0500 - 1500 LST
104	13 April 1988	Spring	Clouds 0500 - 1500 LST
105	14 April 1988	Spring	Clouds 0500 - 1500 LST, Trace of Precipitation 0500 - 1000 LST
106	15 April 1988	Spring	Clouds 0500 - 1500 LST
107	16 April 1988	Spring	Clear Skies, Visibilities Missing
197	16 July 1989	Summer	Clear Skies, Visibilities Missing
198	17 July 1989	Summer	Clear Skies
199	18 July 1989	Summer	Clear Skies
200	19 July 1989	Summer	Clouds 1300 - 1600 LST
201	20 July 1989	Summer	Clouds 0500 - 1600 LST
202	21 July 1989	Summer	Clouds 0500 - 1500 LST
203	22 July 1989	Summer	Clear Skies, Visibilities Missing
287	14 October 1990	Fall	Clear Skies, Visibilities Missing
288	15 October 1990	Fall	Clouds 1100 - 1500 LST
289	16 October 1990	Fall	Clouds 0600 - 1400 LST
290	17 October 1990	Fall	Clouds 0600 - 1500 LST
291	18 October 1990	Fall	Clouds 0600 - 1500 LST
292	19 October 1990	Fall	Clouds 0600 - 1100 LST
293	20 October 1990	Fall	Clear Skies, Visibilities Missing

```
Fort Hunter-Liggett, CA 11 Jan 1990 Winter Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990  1
            Press  Temp   RH  Wd Spd Direct  Vis   Aer  Precip      Cloud Data
Day Time    (mb)   (C)   (%)  (m/s)  (deg)  (km)   H (mm/hr) P  Amt L Amt M Amt H
 11  0 0   980.5   4.8  86.0   1.0   317.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  338.2 165.7  -11.8
 11  1 0   980.1   5.1  83.0   1.0   341.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  337.8 162.6   39.6
 11  2 0   980.1   4.9  83.0   0.5   326.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  336.6 152.7   66.3
 11  3 0   980.2   3.9  86.0   0.7   328.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  331.8 141.1   80.5
 11  4 0   980.2   4.1  86.0   0.8    15.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  332.8 129.0   90.3
 11  5 0   980.6   2.9  91.0   0.5   332.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  327.0 116.9   98.6
 11  6 0   980.4   2.3  93.0   1.3   306.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  324.2 106.1  116.4
 11  7 0   980.3   1.9  94.0   1.0   330.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  322.3  93.7  114.5
 11  8 0   980.8   2.5  94.0   0.5   261.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0   30.0    0.0   30.0  325.1  83.1  123.6
 11  9 0   981.3   6.2  85.0   1.0   317.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0   68.9    0.0   68.9  343.9  73.7  134.0
 11 10 0   981.1  11.5  70.0   0.8   226.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0   99.4    0.0   99.4  369.9  65.9  146.3
 11 11 0   980.6  16.7  55.0   0.8   151.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0  133.4    0.0  133.4  397.9  60.4  160.6
 11 12 0   979.4  17.8  65.0   1.4   107.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0  148.9    0.0  148.9  404.0  58.0  176.6
 11 13 0   978.2  19.3  62.0   1.3   138.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0  142.1    0.0  142.1  412.4  59.0  192.9
 11 14 0   977.3  19.8  49.0   2.3   133.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0  114.4    0.0  114.4  415.2  63.3  208.0
 11 15 0   976.7  21.1  44.0   2.0   130.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0   75.2    0.0   75.2  422.7  70.2  221.2
 11 16 0   976.9  19.3  36.0   3.9   209.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0   31.6    0.0   31.6  412.4  79.0  232.3
 11 17 0   976.9  17.4  39.0   2.0   192.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0   27.6    0.0   27.6  401.8  89.0  241.9
 11 18 0   977.6  14.0  67.0   2.7   126.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  383.2 100.1  250.4
 11 19 0   977.9  12.2  73.0   2.8   119.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  373.8 111.9  258.3
 11 20 0   978.1  12.3  77.0   1.7   182.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  374.1 123.8  266.2
 11 21 0   978.4  11.8  81.0   2.9   164.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  371.6 136.0  -84.8
 11 22 0   978.8  11.5  82.0   2.7   164.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  369.9 147.9  -72.9
 11 23 0   978.9  11.4  84.0   1.8   138.0  24.0   1   0.0   0  1.0 1 0.0 0 0.0 0    0.0    0.0    0.0  369.4 158.7  -53.1
```

Figure 3. Sample Listing of One Day of Meteorological Data for Fort Hunter-Liggett, California

Upper air data are required for the calculation of the flux data. Radiosonde data were collected from Hunter-Liggett but not enough data were obtained for use with the SWOE models. Instead, the model atmospheres built into LOWTRAN7[3] are being used.

The required cloud parameters also suffered from major gaps in the data. In the case of cloud type and heights, no data were reported at all. A decision was made to specify what clouds types were present and to hardwire into the models the cloud base and top heights. Stratus clouds were assumed to be present during the fall and winter and stratocumulus clouds in the spring and summer. The cloud base and top heights were taken from those used in LOWTRAN7:[3]

<u>Stratocumulus:</u>

Base - 0.66 km, Top - 2.0 km

<u>Stratus:</u>

Base - 0.33 km, Top - 1.0 km

3.2 Creation of the SWOETHRM Library of Surface Properties

In the previous version of SWOETHRM, the user was required to describe all of the material properties for the surfaces being studied. Seeing that the list of input properties included parameters that only a material scientist would understand how to obtain, the decision was made to establish a set of default surface types and hardwire the required material properties into a surface properties library. This

library consists of default values for the type of surface being modeled (soil, snow, or water), the type of soil (silt, clay, or sand), and the type of vegetation that can appear on top of the surface (none, simple vegetation, or extended forests). In this way, the user only has to provide a series of names in order to describe the type of surface being studied.

3.2.1 Default Soil Categories

3.2.1.1 Material Properties

Three soil categories have been provided as defaults: silt, clay, and sand. During winter conditions, the surface can also be assumed to be covered with snow. The material properties contained in the SWOETHRM library for these soils are listed in Table 4 and defined as:

Density of Dry Materials

The solid soil particle density excluding water weight and air space volume.

Bulk Density of Dry Materials

The density of dry, naturally occurring soil including air space and any organic material in the soil volume.

Heat Capacity of Dry Material

The amount of heat needed to raise a unit mass of the material by one degree.

Thermal Diffusivity

A measure for the rate at which an imposed temperature gradient in the soil is dissipated by conduction.

Thermal Conductivity

The proportionality constant relating the heat flowing through the soil at the temperature gradient.

Coarseness

Refers to soil texture and the relative proportions of the various soil components (clay, silt, sand) in a given soil.

Plasticity Index

The difference in water content between the liquid and plastic limits of a soil and is an indication of a soil's "clayeness" or potential plasticity.

Surface Albedo at Normal Incidence

The fraction of total solar radiation that is reflected from the surface.

Emissivity

The fraction of thermal radiation emitted by a surface compared to a blackbody.

The values were based on a review of data from the soil science literature (*e.g.* [9,10,11,12,13]) and represent median values. The user need only specify whether a given soil is at the surface or is an underlying layer.

Table 4. Values of Material Properties for the Default SWOE Soil Categories

MATERIAL PROPERTY	SILT	CLAY	SAND
Density of Dry Materials ($kg\ m^{-3}$)	2650	2650	2650
Bulk Density of Dry Materials ($kg\ m^{-3}$)	1130	1130	1550
Heat Capacity of Dry Materials ($J\ kg^{-1}\ K^{-1}$)	850	895	813
Thermal Diffusivity ($cm^2\ min^{-1}$)	Calc	Calc	Calc
Thermal Conductivity of Dry Material ($W\ m^{-1}\ K^{-1}$)	0.42	0.36	0.25
Coarseness Code	"Coarse"	"Fine"	"Coarse"
Plasticity Index	0.15	0.2	0.05
Surface Albedo at Normal Incidence	0.3	0.23	0.4
Emissivity	0.94	0.97	0.92

9 Marshall, T.J., and Holmes, J.W. (1988) Soil Physics, second edition, Cambridge University Press, New York, 374pp.

10 Donahue, R.L., Miller, R.W., and Shickluna, J.C. (1983) Soils: An Introduction to Soils and Plant Growth, Fifth edition, Prentice-Hall, New York, p.57.

11 Brady, N.C. (1984) The Nature and Properties of Soils, Ninth edition, Macmillan Publishing Co., New York, p.52

12 Geiger, R. (1965) The Climate Near the Ground, Harvard University Press, Cambridge, p.29

13 Faroki, O.T. (1981) "Thermal Properties of Soils," US Army Cold Regions Research and Engineering Laboratory, Hanover, NH, CRREL Monograph 81-1, December.

3.2.1.2 Default Initial Soil Temperature and Moisture Profiles

During a calculation, profiles of soil temperature and water content are required for initialization. Calculations are assumed to begin at midnight and, accordingly, four seasonal profiles of soil temperature have been hardwired into SWOETHRM. Currently, the program selects the soil temperature profile whose surface temperature is nearest to the observed air temperature at midnight. Figure 4 shows the four soil temperature profiles for reference. The profiles represent average midnight soil temperatures in south central Maine. If a snow covered surface is being simulated, the winter soil temperature profile is always used.

SWOETHRM uses the the bulk water density to describe a soil water profile. Initial soil water contents at midnight are assigned according to the soil type being modeled. Table 5 lists the default values of soil water content and corresponding bulk water density currently used in SWOETHRM. The value of 18% in Table 5 is based on the value of the average water content of soils in south central Maine during summer conditions. Initial water contents for sand were reduced to 9% because water filtration rates are generally higher for sand. Although snowcover is unlikely at Hunter-Liggett, initialization values have been included for other scene studies. Further study of the literature should be made to determine if these values need to be refined.

3.2.2 Default Vegetation Categories

The SWOETHRM allows for two types of vegetation, simple vegetation and extended forest canopies. Simple vegetation refers to grasses, crops, brush, shrubs, etc. For simple vegetation, a set of seasonal default values has been hardwired into SWOETHRM.

3.2.2.1 Simple Vegetation

The presence of simple vegetation at the surface is handled in SWOETHRM using a subroutine called VEGIE,[14] that moderates the surface energy budget used by SWOETHRM. In previous studies, only two types of simple vegetation have been considered, "high" and "medium" vegetation. In those situations, the "high" and "medium" refer to the density, or fractional coverage, of the vegetation and not the height of the vegetation. Also, the data that were commonly used to describe the two types of vegetation were seasonally independent.

Two significant changes have been made in the consideration of simple vegetation. The first is the addition of a low density vegetation category and the second

[14] Balick, L.K., Scoggins, R.K., and Link, Jr. L.E. (1981) "Inclusion of a Simple Vegetation Layer in Terrain Temperature Models for Thermal Infrared (IR) Signature Prediction," Army Engineer Waterways Experiment Station, EL-81-4, August, ADA 104469.

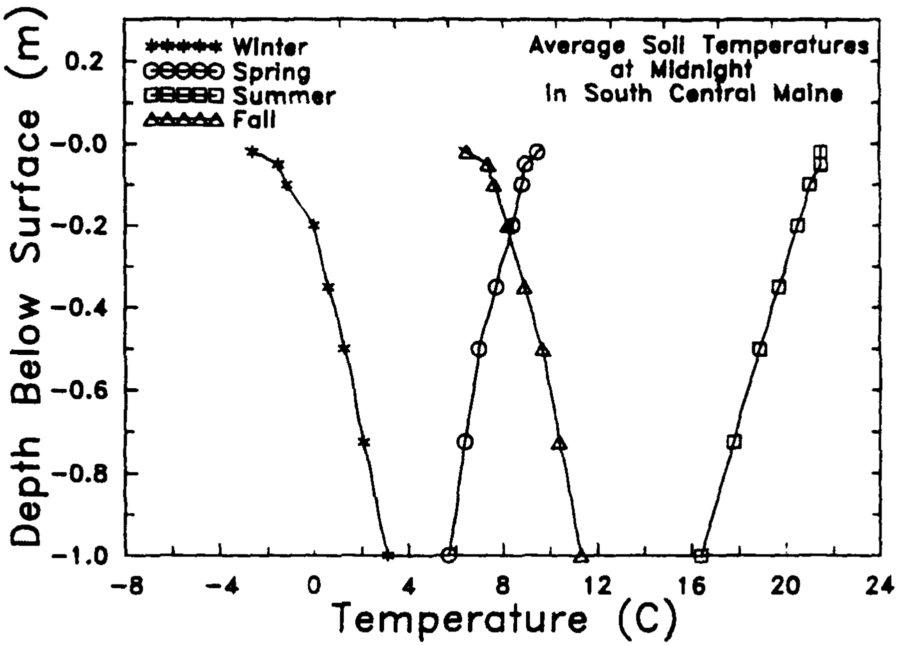

Figure 4. Initial Profiles of Soil Temperature Used By SWOETHRM

Table 5. Initial Soil Water Contents Used By SWOETHRM

SURFACE TYPE	WATER CONTENT (% by vol)	BULK WATER DENSITY (kg/m^3)
Silt	18	180
Clay	18	180
Sand	9	90
Snow	-	160

is the inclusion of seasonally dependent parameters. For the purposes of this effort, the seasons have been defined using the criteria: winter (December - February), spring (March - May), summer (June - August), and fall (September - November). If a calculation spans months that fall in different seasons, the seasonal definition for the starting time period will prevail during the calculations. Table 6 lists the default values being used in SWOETHRM to describe simple vegetation. (It is noted that the values for the longwave emissivity and shortwave absorption were switched in the previous version of SWOETHRM.)

The high density vegetation is assumed to be a managed, economic crop. Medium density vegetation is assumed to be natural, woody, shrub-like vegetation. The low density vegetation is assumed to be a sparse version of vegetation in the medium density category.

The "state of the vegetation" is a term that is intended to account for the changes in stomatal resistance due to factors such as the stage of development of the vegetation and the presence of non- optimal conditions of moisture, temperature, vapor pressure, to name just a few. In VEGIE, the state of the vegetation is a lumped factor that accounts for all stresses that modify stomatal resistance. A more complete treatment would evaluate the effects of non-optimal conditions individually and be dependent upon species (*e.g.*[15,16,17]). The values included in the Table are first order approximations assuming everything is optimal exept the stage of growth of the vegetation. In the winter, when plant transpiration does not occur, the term goes to infinity. In the spring, when buds are breaking and new leaves are appearing, stomatal resistance is slightly higher than that occuring during the summer. As leaves age in the fall, the stomatal resistance increases significantly.

The longwave emissivity of leaves, woody materials, soils, and snow have extremely little seasonal dependence. However, there is a slight seasonal variation with the shortwave absorption.[18,19,20,21]

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15 Baldocchi, D.D., Hicks, B.B., and Camara, P. (1987) A Canopy Stomatal Resistance Model for Gaseous Deposition to Vegetated Surfaces, *Atmos. Environ.*, **21**:91-101.

16 Goltz, S.M., LaCruz, L., Scott, F., and Guan, Z. (1991) Surface Resistance and Evaporatranspiration Models of a Spruce-Fir Forest, Proceedings of the 20th Conference on Agricultural and Forest Meteorology, Salt Lake City, Utah.

17 Jarvis, P.G. (1976) The Interpretation of the Variation in Leaf Water Potential and Stomatal Conductance Found in Canopies in the Field, *Phil. Trans. R. Soc. London, ser B*, **273**:593-610.

18 Hummel, J.R. and Reck. R.A. (1979) A Global Surface Albedo Model, *J. Appl. Meteoro.*, **18**:239- 253.

19 Kondrat'yev, K. Ya (1965) Actinometry, NASA Publication TT- F9712, p.44.

20 Sellers, W.D. (1965) Physical Climatology, University of Chicago Press, p.41.

21 Van Wijk, W.R. (ed.) (1963) Physics of Plant Environment, North-Holland Publishing Co.,

Table 6. Default Values of the Parameters Required by the VEGIE Submodule as a Function of Season for High, Medium, and Low Density Vegetation

DENSITY CATEGORY	VEGIE PARAMETER	WINTER	SPRING	SUMMER	FALL
HIGH					
	Fractional Coverage	0.05	0.40	0.70	0.40
	State of the Vegetation	∞	1.25	1.0	1.67
	Longwave Emissivity	0.96	0.96	0.96	0.96
	Shortwave Absorption	0.70	0.80	0.85	0.75
	Vegetation Height (cm)	5.0	25.0	50.0	25.0
MEDIUM					
	Fractional Coverage	0.15	0.30	0.40	0.30
	State of the Vegetation	∞	1.25	1.0	1.67
	Longwave Emissivity	0.96	0.96	0.96	0.96
	Shortwave Absorption	0.70	0.80	0.85	0.75
	Vegetation Height (cm)	75.0	85.0	100.0	85.0
LOW					
	Fractional Coverage	0.10	0.20	0.30	0.20
	State of the Vegetation	∞	1.25	1.0	1.67
	Longwave Emissivity	0.96	0.96	0.96	0.96
	Shortwave Absorption	0.70	0.80	0.85	0.75
	Vegetation Height (cm)	50.0	50.0	50.0	50.0

3.2.2.2 Extended Forest Canopies

Extended forest canopies are included using the canopy portion from the Thermal Vegetation Canopy Model (TVCM).[22] The default data are for a seasonally independent generic coniferous (Douglas fir) and deciduous (Oak/Hickory). Table 7 lists the data being used. The reader is referred to the TVCM report for specific details about the various parameters.

Amsterdam, p. 91.

22 Smith, J.A., Ranson, K.J., Nguyen, D., Balick, L.K. Link, L.E., Fritschen, L., and Hutchison, B.A. (1981) Thermal Vegetation Canopy Model Studies, *Remote Sens. Environ.*, **11**:311-326.

Table 7. Default Parameters for (a.) Deciduous and (b.) Coniferous Forests

(a.) Deciduous Forest

PARAMETER	TOP LAYER	MIDDLE LAYER	BOTTOM LAYER
Initial Temperature (C)	9.0	9.0	9.0
Leaf Frequency Distribution Type	1.0	1.0	1.0
Leaf Clumpiness Factor	0.1	0.1	0.1
Leaf Area Index	3.4	0.8	0.4
Longwave Emissivity	0.98	0.98	0.98
Shortwave Absorption Coefficient	0.75	0.75	0.75
Leaf Stomatic Resistance to Water Vapor Diffusion (Independent of Layer Location)	0.07		

(b.) Coniferous Forest

PARAMETER	TOP LAYER	MIDDLE LAYER	BOTTOM LAYER
Initial Temperature (C)	9.0	9.0	9.0
Leaf Frequency Distribution Type	1.0	1.0	1.0
Leaf Clumpiness Factor	0.1	0.1	0.1
Leaf Area Index	1.5	5.3	1.0
Longwave Emissivity	0.98	0.98	0.98
Shortwave Absorption Coefficient	0.75	0.75	0.75
Leaf Stomatic Resistance to Water Vapor Diffusion (Independent of Layer Location)	0.66		

3.3 Creation of a Research Grade Input File

SWOETHRM contains a number of input parameters that would only typically be changed by the user performing detailed research-grade calculations. Examples of these inputs are those related to convergence criteria or output conditions. These parameters are contained in a new, optional file called *research.inp*.

In addition to creating this new "research grade" input file, the ordering of the information and the names of some of the program variables have also been changed in order to conform with the ANSI programming standards for variable names within Fortran77. Table 8 lists the names of the parameters in the file *research.inp*, the default values, and a description of the variable. Table 9 lists the old and new names of those variables where changes were made. Finally, Figure 5 lists the file *research.inp*, showing the format being used. It is noted that the file has been constructed so that only one datum is on each record and that explanatory information is provided to describe the variable.

Table 8. Names of Variables in the Optional Research Grade Data File *research.inp*, the Default Values, and Descriptions

VARIABLE NAME	DEFAULT VALUE	DESCRIPTION OF VARIABLE
PINV	12	Print out interval for full subsurface temp profile (hours)
IFLXOT	0	Print out hourly incident heat fluxes (1 = Yes, 0 = No)
ITM	0	Input measured temperature data for comparison (1 = Yes, 0 = No)
IFLTER	0	Print out water infiltration estimates (1 = Yes, 0 = No)
NGOOD	2	Number of successive good calculations before increasing time step
DTMIN	5	Minimum allowable time step (sec)
DTMAX	900	Maximum allowable time step (sec)
DTMINW	1	Minimum allowable time step (sec) when water flow is present
DTMAXW	900	Maximum allowable time step (sec) when water flow is present
DSMAX	0.1	Maximum allowable change in saturation per time step (-)
TMAX	0.05	Maximum allowable temperature (C) estimation error per time step
ITRACK	0	Include snow compaction by tank treads (1 = Yes, 0 = No)
IY2	*	Last two digits of year when tank track data were taken
JDAY2	*	Julian day when tank track data were taken
IHOUR2	*	24 hour time when tank track data were taken
CTRACK	*	Compaction ratio
TRWIDE	*	Track width (m)
TRDEEP	*	Compacted snow depth (m)
TRORNT	*	Orientation of track relative to north (deg)

* Included only if ITRACK = 1. No default values set.

Table 9. Old and New Names of Variables in *research.inp* Changed in Order to Conform With the ANSI Fortran Programming Standards

OLD NAME	NEW NAME
IFLUXOUT	IFLXOT
IOUTFILTRATE	IFLTER
DTSMIN	DTMINW
DTSSMAX	DTMAXW
DSSALLOWED	DSMAX
ERRTALLOWD	TMAX
ITRACKS	ITRACK
TRWIDTH	TRWIDE
TRDEPTH	TRDEEP
ORIENTATION	TRORNT

Figure 5. Listing of the Optional Data File *research.inp* Containing the Research Grade Input Parameters Used by SWOETHRM

```
12     PINV   - Print out interval for full subsurface temp profile (hours)
0      IFLXOT - Print out hourly incident heat fluxes (1 = Y, 0 = N)
0      ITM    - Input measured temp data for comparison (1 = Y, 0 = N)
0      IFLTER - Print out water infiltration estimates (1 = Y, 0 = N)
2      NGOOD  - # of successive good calculations before increasing time step
5.0    DTMIN  - Minimum time step (sec)
900.0  DTMAX  - Maximum time step (sec)
1.0    DTMINW - Minimum time step (sec) when water flow is present
900.0  DTMINW - Maximum time step (sec) when water flow is present
0.1    DSMAX  - Maximum change in saturation per time step
0.05   TMAX   - Maximum temperature (C) estimation error per time step
0      ITRACK - Include snow compaction by tank treads (1 = Y, 0 = N)
       IY2    -  Last two digits of year when tank track data were taken
       JDAY2  - Julian day when tank track data were taken
       IHOUR2 - 24 hour time when tank track data were taken
       CTRACK - Compaction ratio
       TRWIDE - Track width (m)
       TRDEEP - Compacted snow depth (m)
       TRORNT - Orientation of track relative to north (deg)
```

4 ENHANCEMENTS TO THE SWOE THERMAL MODELS

The SWOE Thermal Models are essentially unchanged in terms of the physics in the models from the previous year.[1] However, a few enhancements and modifications have been made to fill in some gaps left over from the previous year or correct a few errors discovered in the models.

4.1 Corrections to the TVCM Implementation in SWOETHRM

A problem in SWOETHRM was discovered where the Thermal Vegetation Canopy Model is coupled to the surface heat conduction portion of the code. It was observed that the longwave fluxes in the canopy were too large for some benchmark cases.

Originally, TVCM was designed as a standalone model with a total of five layers, one for the atmosphere, three canopy layers, and one layer for the underlying surface. During the first year of the BTI/SWOE program, the three forest canopy layers from TVCM were coupled to CTSTM. During the development of the Interim Thermal Model, the same coupling approach used with TSTM[23] was used to couple the canopy layers with SWOETHRM. One of the coupled parameters was the downward longwave flux at the surface from the canopy layers and atmosphere. In the CTSTM implementation of TVCM, the basis of that used in SWOETHRM, this term was discovered to be too high.

After reviewing the CTSTM program and the literature on the development of TVCM,[24] it became clear that an incorrect matrix was used in CTSTM to calculate the downward longwave fluxes at the surface. The TVCM documentation gives expressions for a VF matrix, which is used to define the exiting longwave flux above the canopy. For exiting longwave fluxes below the canopy, the correct expressions are

$$\begin{aligned} VF(1,\theta) &\equiv \text{Open Flux Sky Contribution} \\ &= PGAP(1,\theta)PGAP(2,\theta)PGAP(3,\theta) \end{aligned} \tag{1}$$

$$\begin{aligned} VF(2,\theta) &\equiv \text{Canopy Layer 1 Contribution} \\ &= PHIT(1,\theta)PGAP(2,\theta)PGAP(3,\theta) \end{aligned} \tag{2}$$

$$\begin{aligned} VF(3,\theta) &\equiv \text{Canopy Layer 2 Contribution} \\ &= PHIT(2,\theta)PGAP(3,\theta) \end{aligned} \tag{3}$$

$$\begin{aligned} VF(4,\theta) &\equiv \text{Canopy Layer 3 Contribution} \\ &= PHIT(3,\theta) \end{aligned} \tag{4}$$

[23] Balick, L.K., Link, L.E., Scoggins, R.K., and Solomon, J.L. (1981) "Thermal Modeling of Terrain Surface Elements", U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, EL-81-2, March, (ADA098019).

[24] Smith, J.A., Ranson, K.J., Nguyen, D., and Link, L.E. (1981) "Thermal Vegetation Canopy Studies," Waterways Experiment Station, Vicksburg, Mississippi, EL-81-6, August.

where $PGAP(i, \theta)$ and $PHIT(i, \theta)$ are the probabilities of gaps and hits, respectively, for canopy layer i at declination angle θ below the canopy. ($PGAP(i, \theta)$ and $PHIT(i, \theta)$ are calculated within the TVCM code.) The longwave flux exiting the canopy from the θ direction then equals

$$I(\theta) = VF(1, \theta)I^{\downarrow}_{sky} + VF(2, \theta)\epsilon_1\sigma T_1^4 + VF(3, \theta)\epsilon_2\sigma T_2^4 + VF(4, \theta)\epsilon_3\sigma T_3^4 \quad (5)$$

where ϵ_i and T_i are the canopy layer emissivity and temperature, respectively, σ is the Stefan- Boltzman constant and $I^{\downarrow}_{sky}$ is the open air downward longwave flux. The total downward longwave flux at the surface is then found by integrating over declination angle

$$I^{\downarrow}_{surf} = \int_0^{\frac{\pi}{2}} I(\theta) \sin\theta d\theta. \quad (6)$$

Table 10 shows how the improved coupling formulation affects the ground temperature under the canopy. Note that the Layer 1 temperature is not significantly affected by the new formulation. This is an important observation for SWOE applications where only the layer 1 temperatures are used for the scene rendering.

4.2 Enhancements and Modifications to the 3-D Tree Model

SPARTA's 3-D thermal response model for individual trees, TREETHERM, was developed to calculate the temperature structure of trees with and without leaves. A database for a mountain oak tree found at the Hunter-Liggett study area was used as a generic tree in the scene simulation studies performed in the second year of the BTI/SWOE program. In order to provide more variability in future scene simulations, a second generic tree was assembled for delivery with the final SWOE package. This second tree is smaller (11 m versus 30 m) than the original Hunter-Liggett tree and was based on a tree measured at Eglin AFB in Florida.[25] These two trees are now supplied with the SWOE package as a set of generic trees. During scene simulations, calculations for the two trees are performed at four different orientations relative to the sun, the net result being eight sets of tree temperatures that can be randomly assigned to the trees in a study area.

The thermal properties for the first order representation of the Hunter-Liggett tree (a mountain oak) were taken from lumber properties[26] and modified for an

[25] Dardeau, E.A., Jr., Friesz, R.R., West, H.W., Brown, G.F., Couch, L.E., and Parks, J.A. (1972) "Environmental Characteristics of Munitions Test Sites, Volume IV, Supplemental Characteristics," Waterways Experiment Station, Vicksburg, Mississippi, M-71-3, June.

[26] Lienhard, J.H., (1981), A Heat Transfer Textbook, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1981 p 495

Table 10. Values of the Surface Infrared Flux, Ground Temperature, and Canopy Layer 1 Temperature From the Old and Revised Longwave Coupling Formulations. The results assume a deciduous forest and data for Julian Day 102 at Fort Hunter-Liggett

TIME (hrs)	SURFACE IR FLUX (W/sq m)	OLD GROUND TEMP (C)	CANOPY LAYER 1 TEMP (C)	SURFACE IR FLUX (W/sq m)	REVISED GROUND TEMP (C)	CANOPY LAYER 1 TEMP (C)
000	422	9.7	11.0	348	9.7	11.0
100	424	10.7	8.8	349	8.7	8.8
200	414	10.1	7.0	341	8.0	7.0
300	413	9.9	6.9	340	7.5	6.9
400	405	9.2	5.4	333	7.0	5.4
500	400	8.7	4.7	330	6.4	4.7
600	396	8.5	4.0	327	6.2	4.0
700	447	11.5	12.6	368	8.1	12.6
800	492	15.3	19.7	406	11.1	19.7
900	529	18.6	25.1	436	13.9	25.1
1000	578	22.2	31.9	477	17.1	31.9
1100	585	24.5	32.7	482	19.1	32.7
1200	579	25.4	31.7	477	20.1	31.7
1300	594	26.7	33.8	490	21.3	33.8
1400	579	25.8	31.8	478	21.6	31.8
1500	572	25.3	31.0	472	21.5	31.0
1600	566	25.2	30.1	467	21.2	30.1
1700	553	24.8	28.3	455	20.6	28.3
1800	529	24.4	25.1	436	19.7	25.0
1900	481	20.5	17.9	396	17.3	17.9
2000	455	17.8	13.9	375	14.9	13.9
2100	438	15.6	11.0	361	12.9	11.0
2200	426	13.9	9.0	351	11.3	9.0
2300	422	12.9	8.5	348	10.4	8.4

arbitrary water content. Since the tree model does not currently differentiate between bark, heartwood, and sap wood (although it can) and does not yet have a moisture transport mechanism, using modified lumber properties is a reasonable method of generating woody material thermal properties. When the tree model requires thermal properties of woody material as a function of a variable water content, experimental data for various tree species and water contents are available (*i.e.*[27,28,29].)

[27] MacClean, J. D. (1941), "Thermal Conductivity of Wood", Heating, Piping, Air Conditioning, June.

[28] MacLean, J. D. (1932) "Moisture Content, Specific Gravity, and Air Space in Wood", Transactions of the ASME, November.

[29] Martin, R. E.(1963) "Thermal Properties of Bark", Forest Product Journal, October.

4.2.1 Operation Via the SWOE Command Interface System

One enhancement to TREETHERM has been to include the operation of the model under the SWOE Command Interface System. In the previous versions, TREETHERM was run as a standalone model.[30] This required the user to create all of the data files required to run the code. These data files were not always user-friendly and their creation was a tedious effort. In the present version, all of the required databases are supplied as default databases. By doing this, all that the user is required to supply is if trees are being included in a given scene simulation.

4.2.2 Addition of Radiation Exchange to the Environment

The tree model has been enhanced by the inclusion of an additional infrared flux term in the surface energy balance for woody material. This added flux term is the upwelling infrared radiation flux. In this way, TREETHERM can be coupled in a simple fashion to a specific type of underlying soil. In the earlier version, infrared radiation into the woody components was assumed to be spherically symmetrical.

The upward infrared fluxes are supplied to TREETHERM in a datafile that is either assembled from field data or calculated by SWOETHRM. These upward infrared flux values must be synchronous with the times in the meteorological data input file. Figure 6 shows an example of the upward infrared flux input file. The format for each line of data is the *Julian day* followed by the *Hour*, *Minute*, the upward infrared flux in W m^{-2}, and the reflected solar flux in W m^{-2}. (Should the user wish to study the role of upwelling infrared fluxes on the tree thermal balance or if the upward infrared flux data are not available, the ground infrared data file values should be set to zero (0.0). TREETHERM will then consider the downward (sky) infrared flux as acting hemispherically symmetric to the woody material surfaces.) The data for reflected solar radiation are currently not used in TREETHERM but its addition to the 3-D tree model is anticipated in a future revision.

Under the new approach, the net re-radiation at a surface i is determined by

$$Q_{RE_i} = \alpha_{i_{IR}} (A_{i_\downarrow}\ IR_\downarrow + A_{i_\uparrow}\ IR_\uparrow) - \epsilon_i A_i SF_i \sigma T_i^4 \qquad (7)$$

where Q_{RE_i} is the net infrared flux at surface element i, $\alpha_{i_{IR}}$ is the surface infrared absorptivity, $A_{i_\downarrow}$ and $A_{i_\uparrow}$ are the areas (m^2) of surface i receiving the downward infrared flux $IR_\downarrow$ (in W m^{-2}) and the upward (ground) infrared flux $IR_\uparrow$ (in W m^{-2}), respectively, ϵ_i is the surface emissivity for element i, A_i is the surface

30 Jones, J.R. (1991) "User's Guide for TREETHERM: A 3-D Thermal Model for Single Trees," Phillips Laboratory, Hanscom AFB, Massachusetts, PL-TR-91-2109, 31 March, ADA 240509.

249	0	0	359.0	0.0
249	1	0	330.0	0.0
249	2	0	327.0	0.0
249	3	0	324.0	0.0
249	4	0	321.0	0.0
249	5	0	318.0	0.0
249	6	0	324.0	14.6
249	7	0	345.0	30.6
249	8	0	360.0	93.3
249	9	0	378.0	131.6
249	10	0	389.0	160.1
249	11	0	398.0	176.8
249	12	0	407.0	180.4
249	13	0	409.0	170.6
249	14	0	407.0	148.4
249	15	0	417.0	72.6
249	16	0	403.0	73.3
249	17	0	392.0	27.9
249	18	0	379.0	14.5
249	19	0	353.0	0.0
249	20	0	340.0	0.0
249	21	0	335.0	0.0
249	22	0	330.0	0.0
249	23	0	325.0	0.0
250	0	0	322.0	0.0
D	H	M	UpIR	RFL'D SOLAR

Figure 6. Example of Upwelling (Ground) Infrared Flux Input Data File Used by TREETHERM

area, SF_i is the shape factor (equal to 1), σ is the Stefan-Boltzmann constant, and T_i is the temperature of the surface element i's (K).

Note that the sum of areas $A_{i\downarrow}$ and $A_{i\uparrow}$ is equal to the total surface area for element i, A_i, since no shading is considered for the infrared energy in the tree model at this time. Implementing infrared "shading" requires institution of a radiative interchange scheme between all significant radiative interacting surfaces within the tree's environment. The framework for including this radiative interchange exists in TREETHERM but has not been incorporated at this time.

4.2.3 Calculation of Leaf Cluster Temperatures

The tree model leaf temperature predictions for a single leaf uses the energy balance method of Gates.[31] This method is used to calculate the average temperature within a leaf cluster associated with a particular branch. In calculating the

[31] Gates, D.M. (1964) "Characteristics of Soil and Vegetated Surfaces to Reflected and Emitted Radition," Proceedings IGARD Symposium on Remote Sensing of Environment, 573-600.

leaf cluster temperature, the direct solar flux is modified by the cosine of the angle θ (see Figure 7) between the solar vector $\hat{s}$ and the vector $\hat{z}$ along the longitudinal axis of the branch associated with the leaf cluster of interest.

Figure 8 compares cluster temperatures for two branches over one day with the enhanced leaf cluster temperature approach. In the Figure, leaf cluster 1 is pointing vertically and leaf cluster 2 is horizontal. Note that the leaf cluster temperature predictions will be the same when the direct solar energy is zero (*i.e.*, for night and total cloud cover conditions). This occurs since individual leaf orientations are not modeled for radiative interchange between leaf surfaces and the up and down-welling infrared fluxes. This detail in modeling is not practical considering the highly variable nature of leaf orientation as well as leaf physiology. Instead, a statistical approach is a preferable method of incorporating the effects of leaf cluster orientation to the infrared fluxes for the leaf cluster temperature estimations.

4.2.4 Effects of Wind Speed and Direction on Thermal Response

In the real world, wind can be a highly variable parameter in terms of both wind speed and direction. As a result, the convective exchange involving tree elements can also be highly variable. The meteorological data files that TREETHERM uses, however, contain wind speed and direction values that are typically assembled on an hourly basis. The code assumes that these data are valid over the hourly interval and, thus, we are ignoring the shorter time scale changes in the convective exchange. Sensitivity studies were conducted to determine if this can have a significant impact on TREETHERM's thermal response.

4.2.4.1 Wind Speed

A sensitivity study was conducted for a range of representative trunk diameters. The results of a model with constant wind speed are compared to the results of two linearly varying wind speeds (with the same average wind speed as the constant wind case). The temperature history for the constant and linearly varying (over a meteorological time interval) wind speed cases were predicted for the cardinal points (N, E, W, S).

A set of representative comparisions are presented in Figure 9 for two different trunk diameters. The results shown in Figure 9 are for a tree element on the eastern side of the tree and the environmental conditions are those used in the Hunter-Liggett simulation. In general, the effects of varying the wind speed over the meteorological data interval are more evident when the trunk (or branch) diameter is smaller, the element under consideration is in the sunlight, and when there are large fluctuations in wind speed about the average wind speed. However, the difference in magnitude between constant and varying wind cases over a given

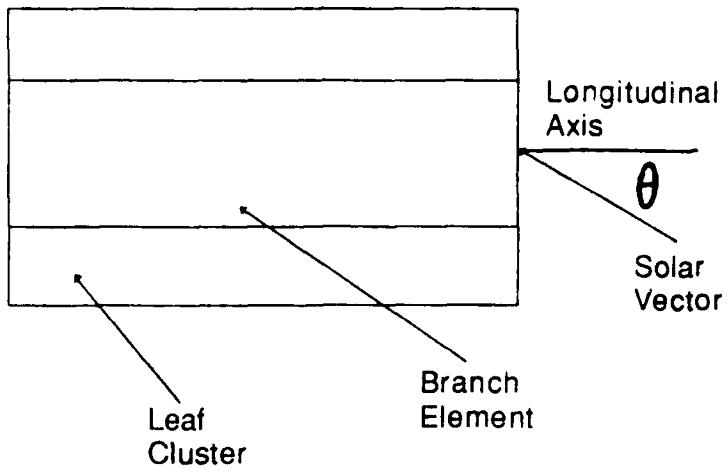


Figure 7. Orientation of Angle θ Used to Modify Direct Solar Flux in Predicting Leaf Cluster Temperature

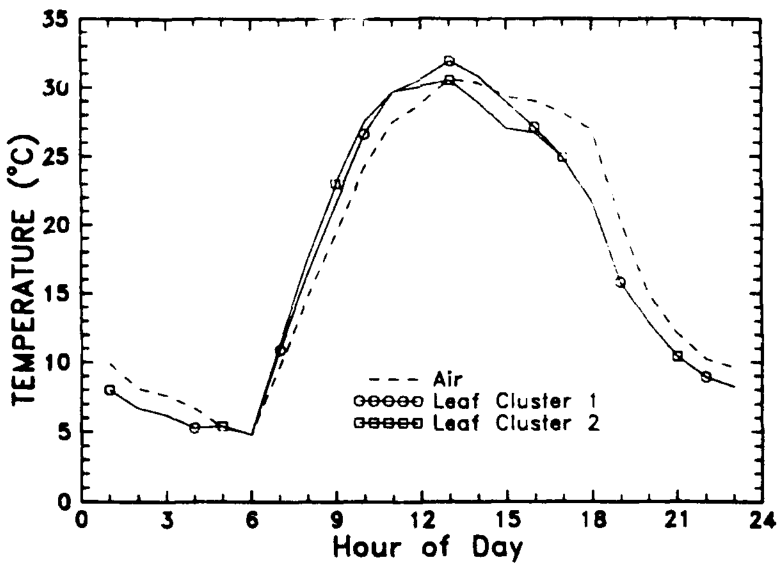
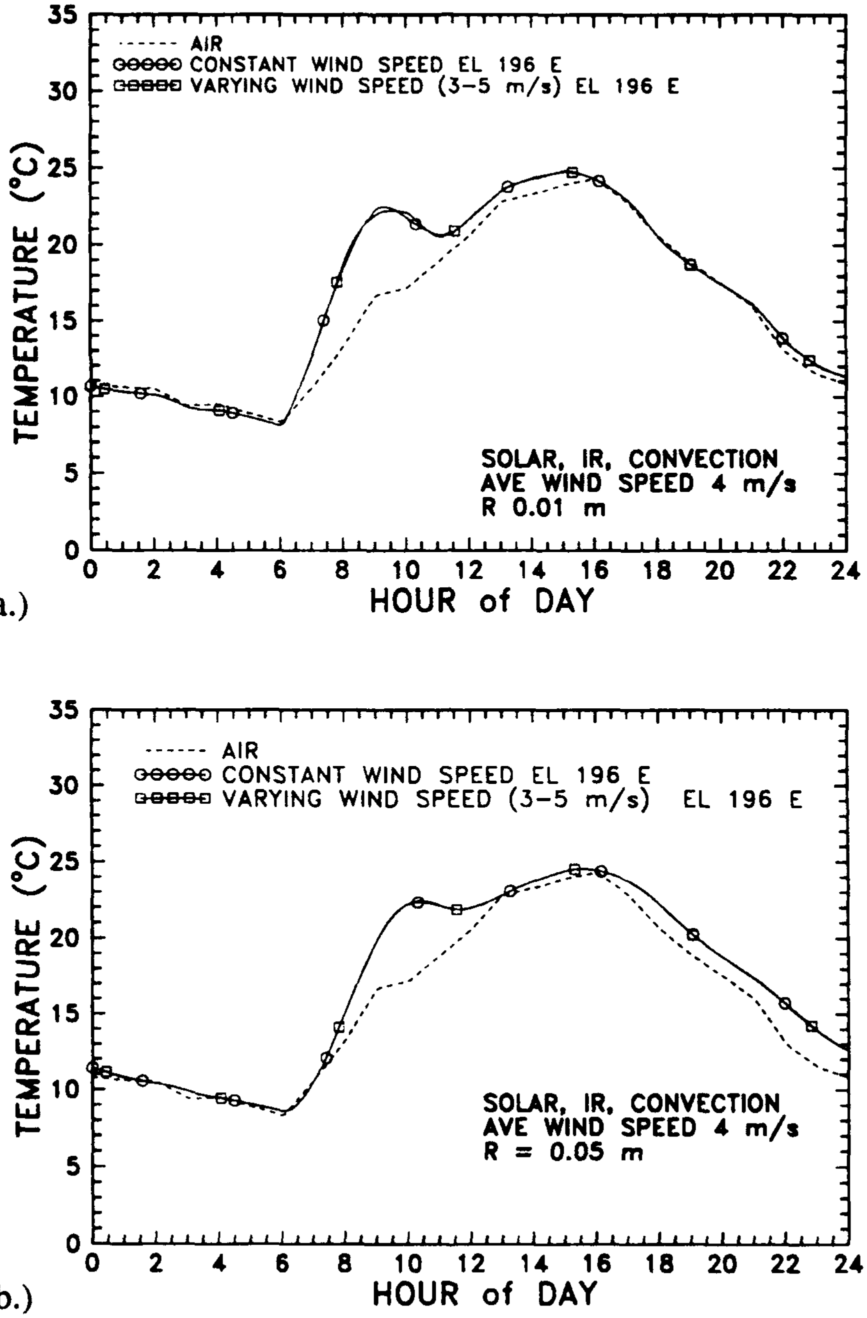


Figure 8. Comparison of Temperatures For Leaf Clusters With Differing Orientation. Leaf cluster 1 is postioned vertically and leaf cluster 2 is horizontal

time interval are not significant for the cases considered here. Therefore, assuming that the wind speed is constant over the given time interval is reasonable.



(a.)

(b.)

Figure 9. Comparison of the Surface Temperatures From TREETHERM as a Function of Time for a Constant (4 m/s) Wind Speed Against Those From a Linearly Varying (3 - 5 m/s) Wind Speed for a Tree Element on the Eastern Side With a Radius Equal to (a.) 0.01 and (b.) 0.05 m

4.2.4.2 Wind Direction

A study was made to examine the feasibility of adding a convective heat transfer mechanism option that was dependent on wind direction as well as wind speed. In the first version of the tree model,[2] an average convective heat transfer coefficient for trunk and branch elements was implemented. This was taken from correlating equations for circular cylinders in cross-flow air for a wide range of Reynolds numbers. The data used in generating these correlating equations for the average convective heat term, $\overline{h}$, are characterized as not having excessive scatter and being relatively free from aspect and tunnel blockage effects. The experiments that produced these data usually had a uniform cylinder surface temperature or a uniform applied heat flux.

In the "real world," the convective heat transfer around a cylindrical surface in a cross-flow is not uniform. The air flow around the cylinder is not uniform, giving rise to stagnation points. This impacts the convective heat transfer through the Nusselt number Nu_D which can then be described as a function of angle, θ, from the forward stagnation point. There are limited data on $Nu_D(\theta)$ for cylinders and almost none on non-cylindrical surfaces or rough surfaces, conditions that are most representative of tree elements.

An examination of the impact of using an angularly dependent heat transfer coefficient has been made. Calculations have been made assuming an angular dependence in Nu_D for a cylindrical element. Figure 10 displays those results and compares them against the average heat transfer coefficient. The calculations in Figure 10 are for one element of the "large" Hunter-Liggett tree. As noted in the Figure, there is little difference between the two sets of results.

In order to properly account for wind direction effects in the convective heat transfer coefficient, one must have data on the true shape of the trunk and branch elements as well as information on the roughness. Also, one would have to be able to model the impact on the wind flow from tree elements and leaves that block the wind, thereby disturbing the wind flow around subsequent elements. These data are not easily obtained and including them would require a highly complex hydrodynamic model. While it is recognized that using an average heat transfer coefficient is not theoretically correct, it is felt that it is a reasonable assumption to make considering the difficulties in obtaining the data and modeling complexities required to properly account for it.

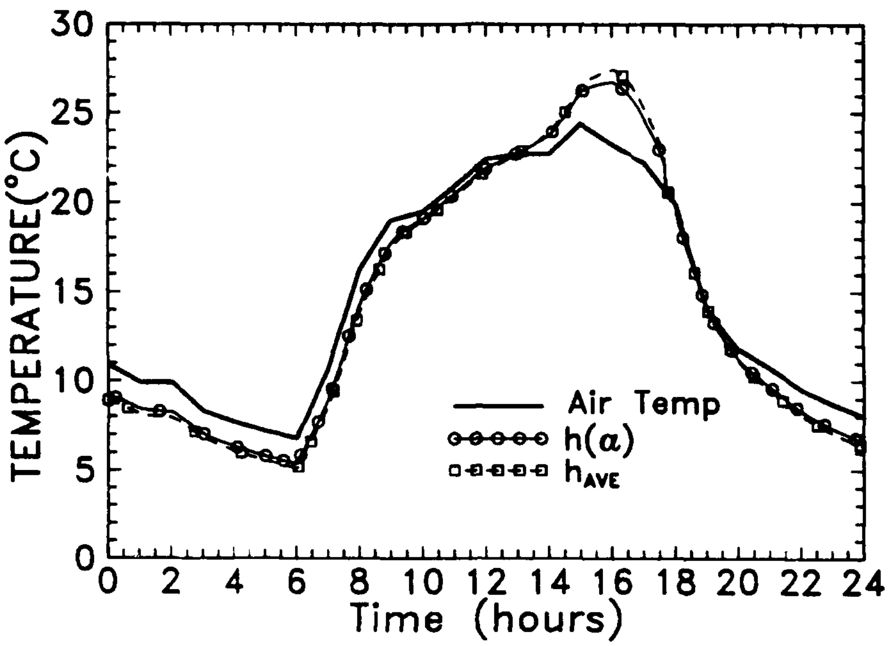


Figure 10. Comparison of Using an Average Heat Transfer Coefficient Against a Heat Transfer Coefficient That has an Angular Dependence Relative to the Forward Stagnation Point on Surface Temperatures on a Tree Element. The calculations assume a constant wind speed of 5 m/s from the west

4.3 Development of an Interim Atmospheric Radiative Transfer Package

An Interim Atmospheric Radiative Transfer Package (IARTP) was developed to calculate the solar and longwave fluxes required by the SWOE physics models. The package is based on LOWTRAN7[3] with a special provision to account for partly clear or cloudy conditions. (LOWTRAN7 performs calculations assuming 100 % clear or cloudy conditions.) The surface weather observations from the meteorological data are used to provide the inputs as required by LOWTRAN7. The appropriate solar zenith angles are calculated for each time in the meteorological data file. Standard LOWTRAN7 input files are created by the IARTP and after executing LOWTRAN7, the spectral flux results are integrated to obtain broadband solar and infrared fluxes.

4.3.1 Clear and Cloudy Conditions

Radiative transfer through a completely clear or cloudy atmosphere can be adequately described from the LOWTRAN7 calculations alone. To do this, an input file for LOWTRAN7 where the assumed path is from space to the ground and the sun's position is placed directly behind the viewer's back (as recommended in the LOWTRAN7 User's Guide.[3]) The atmospheric package then obtains from

LOWTRAN7 (via the standard *tape8* output file) the spectral values of direct solar irradiance at the ground plus the corresponding diffuse solar and infrared vertical fluxes. When a cloud is specified, the calculated diffuse solar and infrared fluxes represent fully overcast conditions.

Separate LOWTRAN7 calculations for the solar and infrared fluxes are performed in order to accurately describe these spectral regions and to reduce the computational burden. For the solar fluxes, calculations are performed between 5,000 and 33,500 cm^{-1} in steps of 500 cm^{-1}. For the infrared fluxes, calculations are performed between 100 and 3,500 cm^{-1} in steps of 50 cm^{-1}. The IARTP does not compute solar fluxes when the sun is below the horizon.

4.3.2 Partly Cloudy Conditions

The general problem of modeling solar and longwave fluxes at the ground is more complicated for partly cloudy conditions. When partly cloudy conditions are reported in the meteorological data, the IARTP provides average hourly solar fluxes, as well as values for clear and cloudy skies. Average hourly solar fluxes are approximated as

$$S_{pc}^{dir} = (1 - C)S_{clr}^{dir} + CS_{cld}^{dir} \tag{8}$$

$$S_{pc}^{dif} = (1 - C)S_{clr}^{dif} + CS_{cld}^{dif} \tag{9}$$

where S_{clr}^{dir} and S_{cld}^{dir} are the direct solar fluxes for clear and cloudy skies, S_{clr}^{dif} and S_{cld}^{dif} are the diffuse solar fluxes for clear and cloudy skies, and C is the observed cloud cover. In the case of the environmental data assembled for Fort Hunter-Liggett, C represents the observed low cloud cover because middle and high clouds were not reported.

For partly cloudy conditions, the IARTP only provides average hourly values of longwave fluxes. Average hourly longwave fluxes are approximated as

$$L_{pc} = (1 - C)L_{clr} + CL_{cld} \tag{10}$$

where L_{clr} and L_{cld} are longwave fluxes for clear and cloudy skies. Future SWOE efforts will include improved radiative transfer formulations for both the solar and infrared fluxes.

4.3.3 Generating Atmospheric Profiles

In order to obtain the solar and infrared fluxes from the IARTP, LOWTRAN7 requires a full atmospheric profile. The upper air data obtained from the Hunter-Liggett area were, unfortunately, not complete enough for use in providing the LOWTRAN7 inputs. Therefore, a provision was made for the IARTP to create the atmospheric profiles based on the model atmospheres resident within LOWTRAN7. The IARTP scales a LOWTRAN7 model atmosphere to match the surface observations in the meteorological data file. The scaled profile is then included in the input file for LOWTRAN7. Using the simulation day and site latitude, the atmospheric package internally determines which model atmosphere is to be scaled. For Hunter-Liggett, the midlatitude fall/winter and spring/summer model atmospheres are used.

The IARTP uses a model atmosphere temperature profile below the tropopause, but shifts it by a constant amount to match the observed surface temperature. If the observed surface temperature is 30° C and the model atmosphere temperature at the station altitude is 20° C, for example, then 10° C is added to each layer temperature. Above the tropopause, model atmosphere temperatures are always used without any shifting. To avoid potential discontinuities at the tropopause, the layer temperature below the tropopause is a linear interpolation of the adjacent layer temperatures. Figure 11 shows how temperature profiles are obtained when model atmosphere temperatures are shifted to match surface values.

Model water vapor profiles are also shifted below the tropopause so they agree with the observed surface water vapor amount, in ppmv. After the temperature and water vapor profiles are shifted, relative humidities are computed for each layer to make sure they don't exceed 100%. If a relative humidity exceeding 100% is found, then the water vapor content for that layer is reduced so it represents a 100% relative humidity. Model atmosphere amounts are adopted for other minor and trace gases.

4.3.4 Aerosols and Clouds

The effects of boundary layer aerosols on solar and longwave fluxes are considered by means of the observed aerosol flag and surface visibility in the meteorological data file. These parameters are passed into the input file for LOWTRAN7. Above the boundary layer, background values for aerosol amounts are used. Also, the IARTP always invokes LOWTRAN7's multiple scattering option.

The treatment of clouds in the atmospheric package follows LOWTRAN7's approach so that cloud bases and tops are defined along the height grid for the atmospheric profile. The IARTP only computes fluxes for low clouds because the meteorological data for Fort Hunter-Liggett only contains observed low cloud

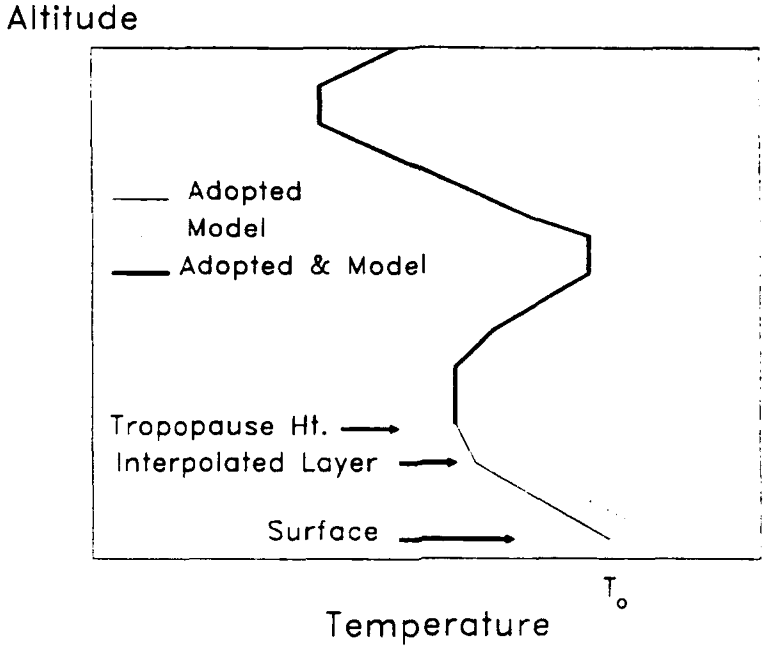


Figure 11. Adopted Temperature Profile When Model Atmosphere Profiles Are Shifted To Match Surface Values. Temperature and altitude axes are for instructive purposes and are not drawn to scale. T_o is the observed surface temperature

cover. In order to have consistency with the cloud shadow model,[7] stratus, stratocumulus, or nimbostratus clouds can be specified in the meteorological file. Other types of low clouds, such as cumulus, are not allowed because they are currently not included in the cloud shadow model.[7] When rain is observed, however, solar and longwave fluxes may represent cumulus clouds because the type of low cloud is determined by the rain rate in LOWTRAN7. This is not a major problem because the cloud shadow is not used for overcast conditions which accompany the rain.

4.3.5 Atmospheric Package Output

Unless solar and infrared flux data have been provided with a meteorological data file, the IARTP calculates the required parameters and modifies the meteorological file associated with a simulation. Specifically, it appends hourly values of:

1. Average solar and longwave flux under the observed cloud coverages
2. Solar zenith and azimuth

The data are calculated for each time period contained in the meteorological data file. The IARTP also creates two additional data files that are required by other models during a SWOE simulation. Specifically, IARTP creates files containing:

1. Cloud base and top altitudes (above ground level) for low, medium, and high clouds as modeled by LOWTRAN7
2. Average direct and diffuse solar fluxes, plus values under completely clear and cloudy conditions.

Both of these files are created in the directory containing the meteorological data. The cloud data are given the same root name as the meteorological data file with a "*.cbs*" extension. The solar flux data are given the meteorological file name with a "*.sol*" extension. (See Appendix B for a discussion of how these data files are constructed.)

4.3.6 Example Calculations

Figures 12 and 13 show calculated values of solar and longwave flux at Fort Hunter-Liggett, California for 9 January 1990 and 19 July 1989, respectively. The weather on 9 January 1990 was clear except for early morning fog between 0600 and 0900. The weather on 19 July 1989 was clear until 1300 with scattered clouds thereafter.

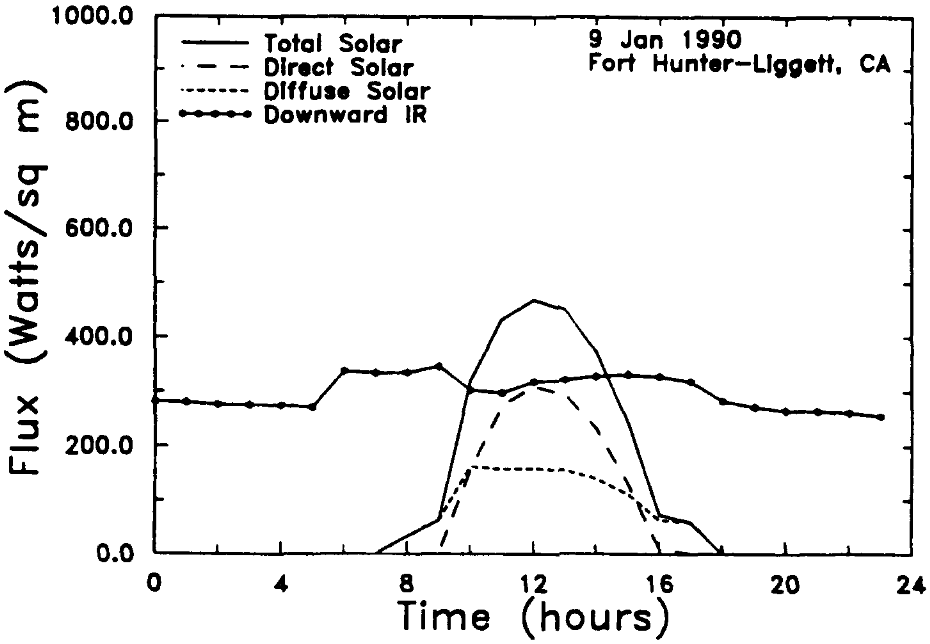


Figure 12. Average Hourly Solar and Infrared Fluxes for 9 January 1990 at Fort Hunter-Liggett as Calculated with the IARTP

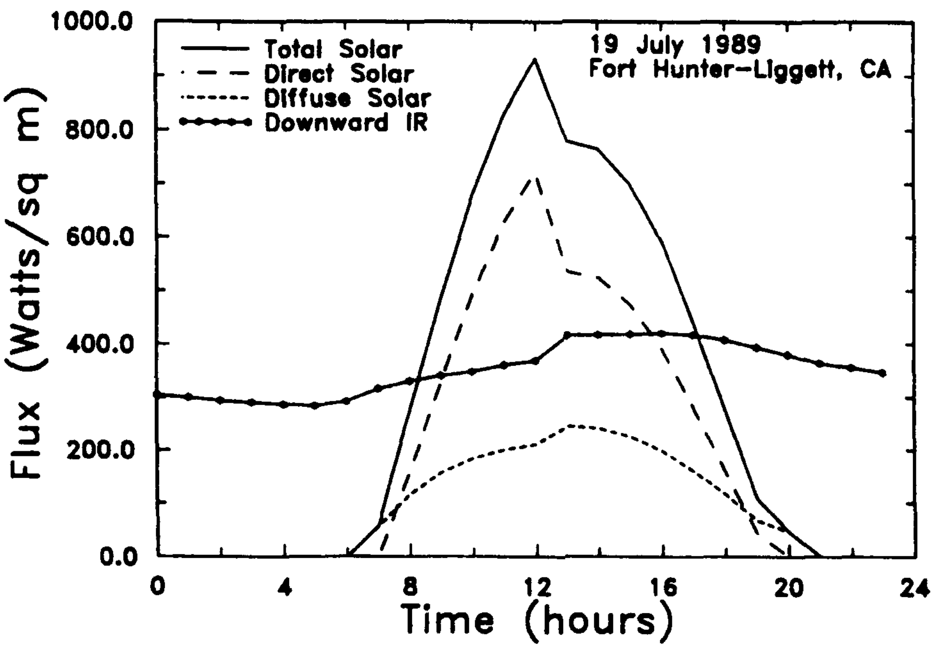


Figure 13. Average Hourly Solar and Infrared Fluxes for 19 July 1989 at Fort Hunter-Liggett, California as Calculated with the IARTP

5 SENSITIVITY CALCULATIONS WITH ENHANCED SWOETHRM

A series of sensitivity calculations were performed with the enhanced version of SWOETHRM, and the results were compared against those from the C language version of the Terrain Surface Temperature Model (CTSTM).[23] Table 11 compares the two models. There are two primary differences between SWOETHRM and CTSTM. First, SWOETHRM (which is based on the winter surface model SNTHERM.89[32] developed at the US Army Cold Regions Research and Engineering Laboratory) is applicable for surfaces containing snow and ice. Second, SWOETHRM also considers the role of dry and moist fluids in soils in the heat balance treatment.

Table 11. Comparison of Model Features of SWOETHRM and CTSTM

FEATURE	SWOETHRM	CTSTM
Surface Types		
Non-Winter Surfaces	Yes	Yes
Winter Surfaces	Yes	No
Non-Vegetated	Yes	Yes
Simple Vegetation	Yes	Yes
Forest Canopies	Yes	Yes
Subsurface Layering	Yes	Yes
Thermal Conduction	Yes	Yes
Convective Cooling	Yes	Yes
Vaporization	Surface and In-Depth	Surface
Melting/Freezing	Yes	No
Mass Addition	Yes	No
Fluid Flow	Yes	No

Comparisons between the enhanced SWOETHRM and CTSTM were performed for two days at Fort Hunter-Liggett, California. The days were 11 January 1990 (Julian Day 11) and 11 April 1988 (Julian Day 102). The weather on 11 January

[32] Jordan, R. (1991) "A One-Dimensional Temperature Model for a Snow Cover, Technical Documentation for SNTHERM.89," US Army Cold Regions Research and Engineering Laboratory, Hanover, NH, Special Report 91-16, October.

1990 was overcast all during the day and the weather on 11 April 1988 was generally clear with scattered clouds during the morning and early afternoon. For reference, Tables 12 and 13 list the observed surface weather conditions for these days. No precipitation was reported on either day.

Figures 14 and 15 show the incident solar and longwave fluxes for 11 January 1990 and 11 April 1988, respectively, as calculated with the IARTP and the solar and infrared flux parameterizations contained in CTSTM. In Figure 15, the solar fluxes from CTSTM are much greater than those from the ITM atmospheric package for two reasons. First, the CTSTM solar flux algorithm does not consider aerosol effects, thereby overestimating the incident solar flux. Second, under partly cloudy conditions, the CTSTM algorithm reduces solar fluxes according to the cloud cover amount squared whereas the IARTP assumes a linear reduction. The cloudy sky reduction approach used in CTSTM is empirical while that used in IARTP is based on an assumption of random overlapping clouds. It is presumed that the use of random overlapping clouds is "more physically realistic," but this issue needs to be studied further.

Sensitivity calculations for SWOETHRM and CTSTM were first performed using the solar and infrared fluxes generated within their respective models. Furthermore, to help study the effects of the different flux algorithms, calculations for CTSTM were performed using the fluxes from the IARTP.

The sensitivity calculations were performed for three land use categories: a bare soil consisting of clay, medium vegetation on top of clay, and a deciduous forest. Note that the term "medium vegetation" refers to the concentation of vegetation, not the height of the vegetation. Every attempt was made to match the thermal and physical properties for clay in the SWOETHRM and CTSTM models. However, it was difficult to precisely match the soil moisture amounts in the two models because the two models define it differently.

Figures 16 and 17 compare the bare soil temperatures from SWOETHRM against those from CTSTM for 11 January 1990 and 11 April 1988, respectively. For 11 January 1990, the calculated soil temperatures from the SWOETHRM are about 3°C higher than those from CTSTM throughout the day. Because downwelling infrared fluxes are a dominant energy term during cloudy conditions, the temperature differences can be attributed, in part, to the slightly higher infrared fluxes that were calculated with the IARTP. For 11 April 1988, the calculated soil temperatures from SWOETHRM are about 2°C higher than those from CTSTM before sunrise. After sunrise, however, the soil temperatures from CTSTM become about 5°C greater than those from SWOETHRM. These differences are primarily due to the larger solar flux values in CTSTM. Also, soil temperatures from SWOETHRM tend to be less responsive to environmental conditions than

Table 12. Surface Weather Observations for Fort Hunter-Liggett, California for 11 January 1990, Julian Day 11

TIME (LST)	TEMP (C)	RH (%)	VISIBILITY (km)	CLOUD TYPE	CLOUD COVER (%)	WIND SPEED (m/sec)	WIND DIRECTION (deg)	SURFACE PRESS (mb)
0000	4.8	86	24	St	100	1.0	317	980.5
0100	5.1	83	24	St	100	1.0	341	980.1
0200	4.9	83	24	St	100	0.5	326	980.1
0300	3.9	86	24	St	100	0.7	328	980.2
0400	4.1	86	24	St	100	0.8	15	980.2
0500	2.9	91	24	St	100	0.5	332	980.6
0600	2.3	93	24	St	100	1.3	305	980.4
0700	1.9	94	24	St	100	1.0	330	980.3
0800	2.5	94	24	St	100	0.5	261	980.8
0900	6.2	85	24	St	100	1.0	317	981.3
1000	11.5	70	24	St	100	0.8	226	981.1
1100	16.7	55	24	St	100	0.8	151	980.6
1200	17.8	55	24	St	100	1.4	107	979.4
1300	19.3	52	24	St	100	1.3	138	978.2
1400	19.8	49	24	St	100	2.3	133	977.3
1500	21.1	44	24	St	100	2.0	130	976.7
1600	19.3	36	24	St	100	3.9	209	976.9
1700	17.4	39	24	St	100	2.0	192	976.9
1800	14.0	57	24	St	100	2.7	125	977.6
1900	12.2	73	24	St	100	2.8	119	977.9
2000	12.3	77	24	St	100	1.7	182	978.1
2100	11.8	81	24	St	100	2.9	154	978.4
2200	11.5	82	24	St	100	2.7	154	978.8
2300	11.4	84	24	St	100	1.8	138	978.9

those from CTSTM (using the solar and infrared fluxes calculated with IARTP) which suggests that the clay may have been modeled with more soil moisture in SWOETHRM than in CTSTM.

Figures 18 and 19 compare the effective temperatures of a surface with medium vegetation and clay underneath from SWOETHRM against those from CTSTM for 11 January 1990 and 11 April 1988, respectively. When simple vegetation is included, the effective temperature, T_e, represents the radiometric temperature of a plot of land that is partially covered by vegetation

$$\epsilon_e T_e^4 = f \epsilon_f T_f^4 + (1 - f) \epsilon_g T_g^4 \tag{11}$$

where ϵ_e is an effective emissivity for the vegetation and underlying ground, f

Table 13. Surface Weather Observations for Fort Hunter-Liggett, California for 11 April 1988, Julian Day 102

TIME (LST)	TEMP (C)	RH (%)	VISIBILITY (km)	CLOUD TYPE	CLOUD COVER (%)	WIND SPEED (m/sec)	WIND DIRECTION (deg)	SURFACE PRESS (mb)
0000	11.0	39	24	Clear	0	0.8	334	978.8
0100	9.9	42	24	Clear	0	0.7	330	978.6
0200	8.1	48	24	Clear	0	0.6	321	978.2
0300	7.6	49	24	Clear	0	0.9	20	977.9
0400	6.7	57	24	Clear	0	0.4	339	977.6
0500	5.3	61	24	StCu	30	0.8	297	977.3
0600	3.8	73	24	StCu	30	0.9	303	977.8
0700	9.7	62	24	StCu	30	0.3	116	978.3
0800	14.7	43	24	StCu	30	0.5	278	978.2
0900	19.4	27	24	StCu	30	0.7	223	978.2
1000	24.2	16	24	StCu	30	0.6	145	977.8
1100	27.5	13	24	StCu	30	1.1	121	977.3
1200	28.8	12	24	StCu	30	2.2	114	976.4
1300	30.6	11	24	StCu	30	1.8	204	975.6
1400	30.3	10	24	StCu	30	3.5	208	975.2
1500	29.3	11	24	Clear	0	3.4	221	974.8
1600	29.0	11	24	Clear	0	2.7	200	974.6
1700	28.1	11	24	Clear	0	2.0	186	974.4
1800	26.9	12	24	Clear	0	0.7	246	974.3
1900	20.2	16	24	Clear	0	0.6	999	974.7
2000	15.0	32	24	Clear	0	0.9	331	975.3
2100	12.1	37	24	Clear	0	0.8	326	975.9
2200	10.2	45	24	Clear	0	0.6	333	976.1
2300	9.6	45	24	Clear	0	0.6	298	976.0

is the fraction of land covered by vegetation, ϵ_f and ϵ_g are the emissivities of the vegetation and ground, respectively, and T_f and T_g are the temperatures of the vegetation and ground, respectively. The effective temperature is obtained by solving for T_e.

As seen in Figure 18 for 11 January 1990, the effective temperatures before sunrise from SWOETHRM are 3° C greater than those from CTSTM. After sunrise, the effective temperatures from the two models are similar. Also, it is worth noticing that the effective temperatures of medium vegetation and clay are very similar to those for bare clay alone because of the overcast conditions and because the seasonally-dependent contribution from medium vegetation to the effective temperature is small (f=0.15).

As seen in Figure 19 for 11 April 1988, the effective temperatures from

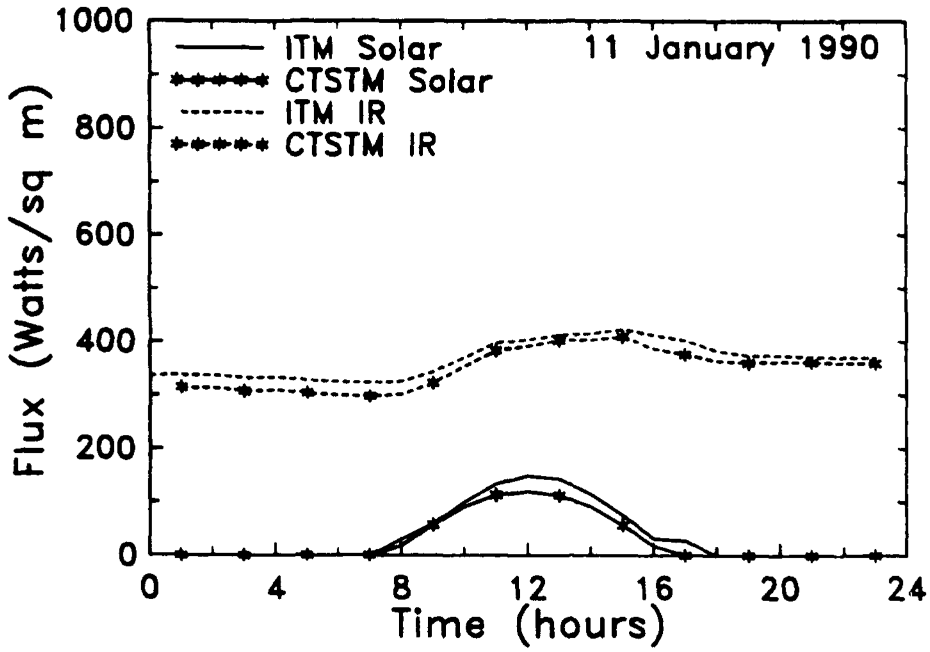


Figure 14. Average Hourly Solar and Longwave Fluxes for 11 January 1990 at Fort Hunter-Liggett, California as Calculated with the SWOE Interim Atmospheric Radiative Transfer Package and That in CTSTM

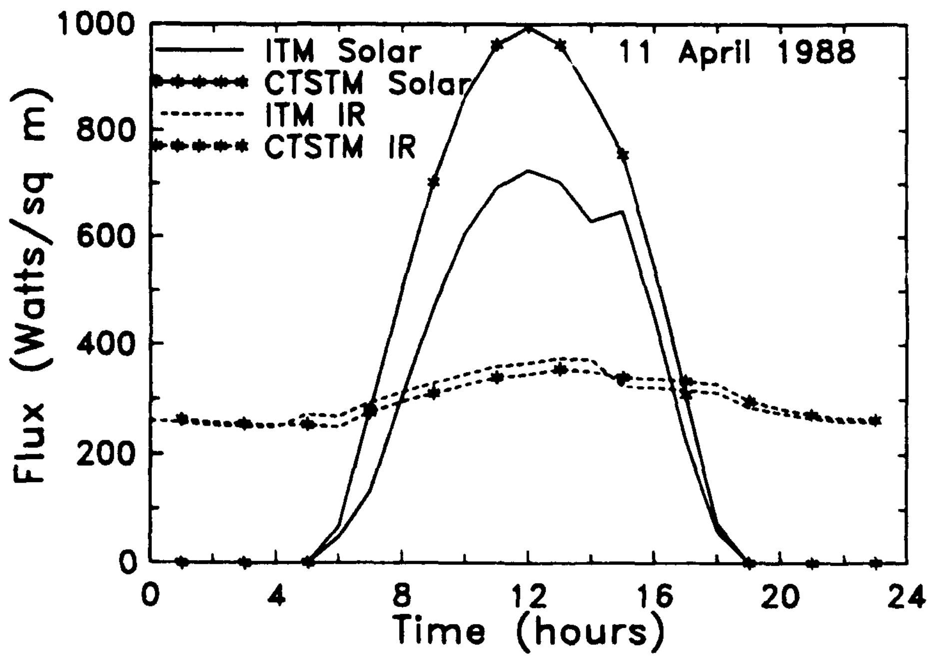


Figure 15. Average Hourly Solar and Infrared Fluxes for 11 April 1988 at Fort Hunter-Liggett, California as Calculated with the SWOE Interim Atmospheric Radiative Transfer Package and That in CTSTM

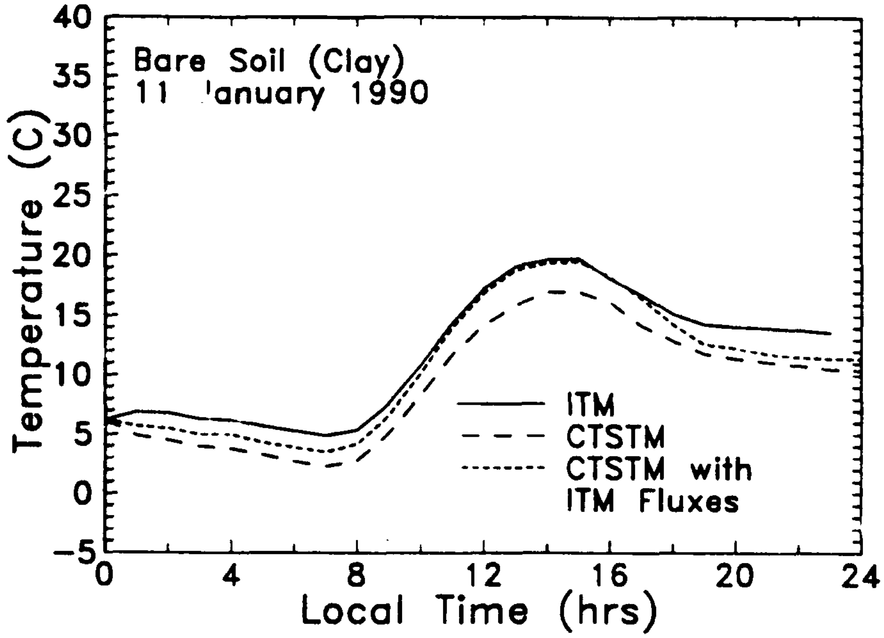


Figure 16. Bare Soil Temperatures from SWOETHRM and CTSTM for 11 January 1990 at Fort Hunter-Liggett, California

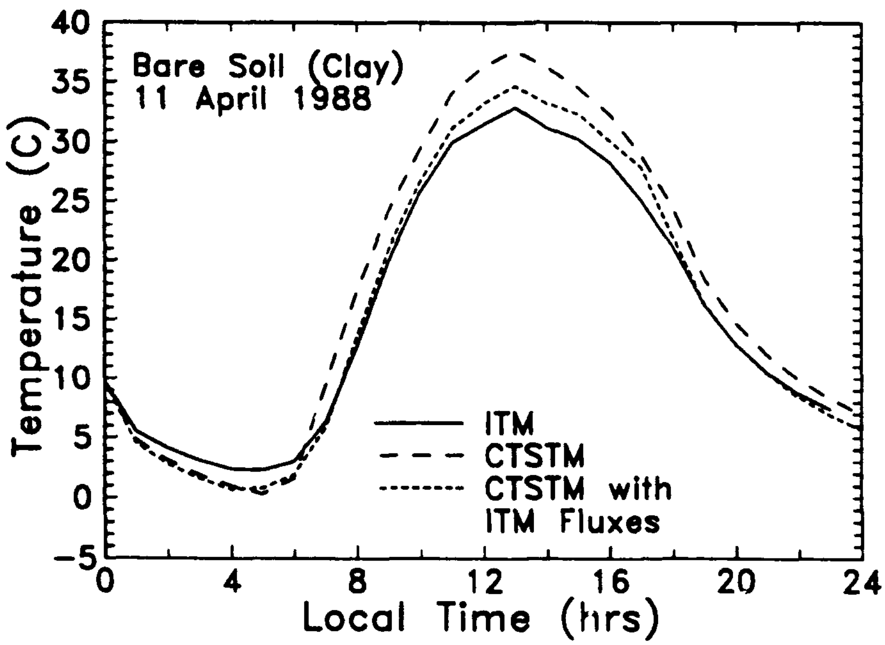


Figure 17. Bare Soil Temperatures from SWOETHRM and CTSTM for 11 April 1988 at Fort Hunter-Liggett, California

SWOETHRM and CTSTM are nearly identical before sunrise. Between about 0800 and 1200, the effective temperatures from CTSTM are 3°C greater than those from SWOETHRM as a result of additional solar heating in CTSTM. After 1200, however, the two models give approximately the same effective temperatures, probably because higher wind speeds act as cooling agents. Also, it is worth noticing that the effective temperatures of medium vegetation and clay are 5 to 15°C less than those for bare clay alone, regardless of which model is used.

Finally, Figures 20 and 21 compare the temperatures from SWOETHRM against those from CTSTM for 11 January 1990 and 11 April 1988, respectively, for a surface with deciduous forest. For 11 January 1990, SWOETHRM and CTSTM predict essentially the same temperatures for the top canopy layer because the solar fluxes from SWOETHRM and CTSTM are similar and because the underlying ground temperature has little or no impact on the top canopy layer. (Note that in both SWOETHRM and CTSTM, the canopy thermal model internally calculates longwave fluxes from the atmosphere, so the different longwave fluxes depicted in Figure 14 are not reflected in these calculations.) For 11 April 1988, the top layer canopy temperatures from CTSTM are about 3°C greater than those from SWOETHRM during the daytime which is directly related to the additional solar fluxes calculated by CTSTM.

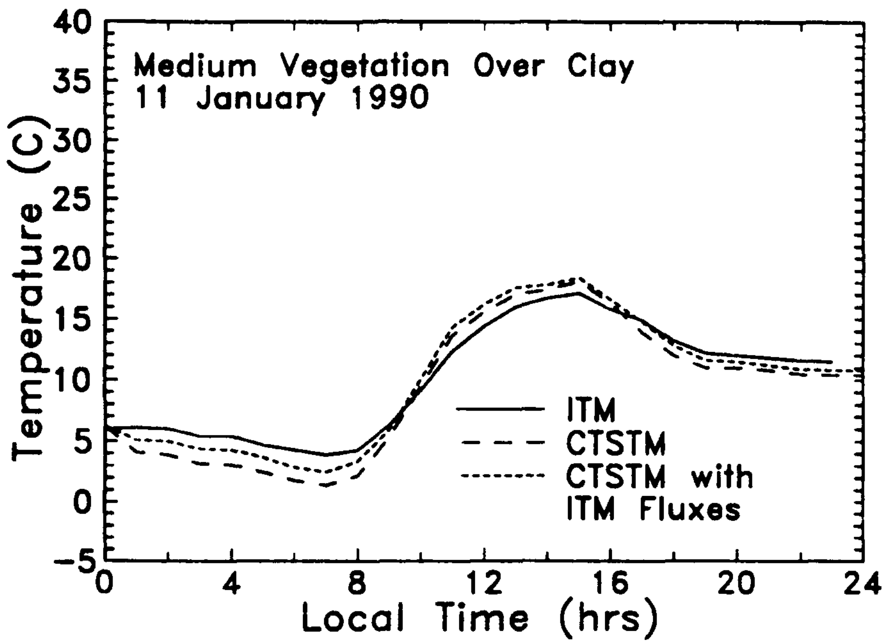


Figure 18. Effective Temperatures of Medium Vegetation and Clay Underneath from SWOETHRM and CTSTM for 11 January 1990 at Fort Hunter-Liggett, California

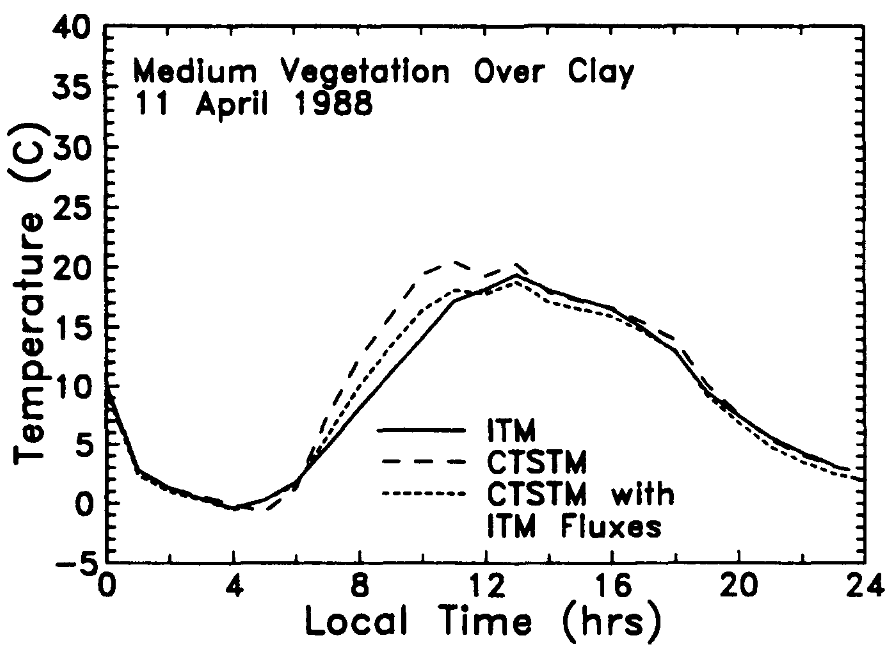


Figure 19. Effective Temperatures of Medium Vegetation and Clay Underneath from SWOETHRM and CTSTM for 11 April 1988 at Fort Hunter-Liggett, California

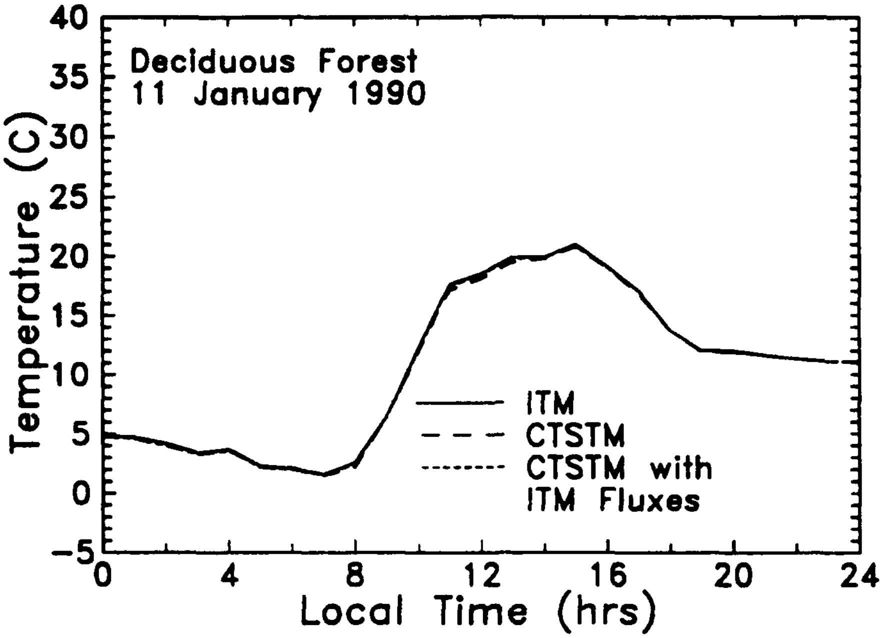


Figure 20. Comparison of Deciduous Forest Temperatures from SWOETHRM Against Those From CTSTM for 11 January 1990 at Fort Hunter-Liggett, California. The temperatures represent the top layer of the forest canopy

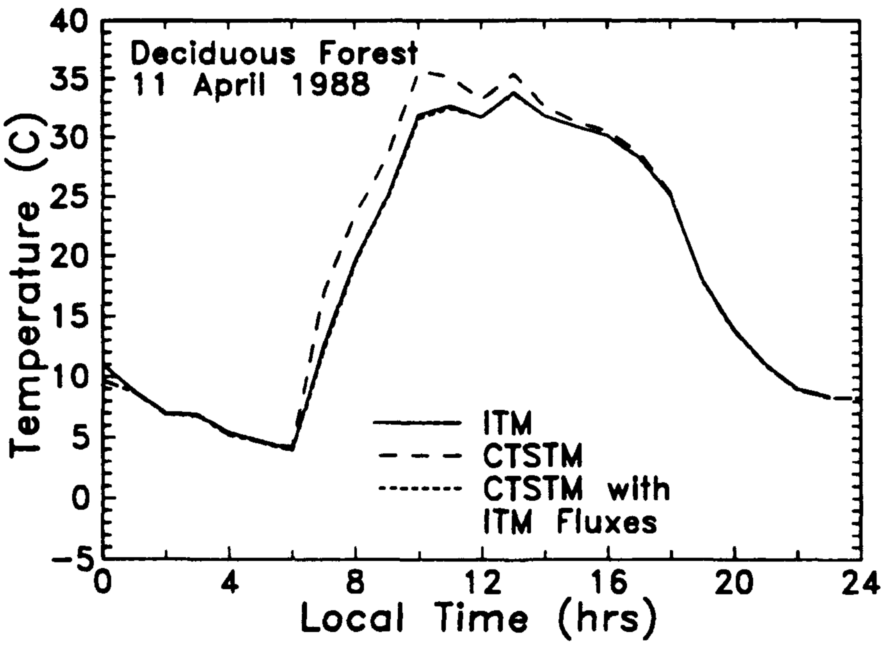


Figure 21. Comparison of Deciduous Forest Temperatures from SWOETHRM Against Those From CTSTM for 11 April 1988 at Fort Hunter-Liggett, California. The temperatures represent the top layer of the forest canopy

6 USERS GUIDE FOR THE COMMAND INTERFACE SYSTEM

6.1 Overview of the Command Interface System

A Command Interface System (CIS) has been developed for the SWOE system to aid the user in performing calculations with the SWOE thermal, cloud, radiance and scene rendering models. The SWOE CIS is designed to assist the user in creating the necessary input files to run the SWOE models. Once the input files have been created, the CIS then executes the calculations.

The SWOE CIS allows the user to perform two different types of calculations. The first is referred to as a "scene simulation" and the second is referred to as "research grade calculations". In a scene simulation, the goal is to produce a radiant field for a given set of terrain descriptions (location and land use catagories), time of day, environmental conditions, and viewing conditions. In a research grade calculation, the goal is to make a more detailed examination of the physics controlling the surface temperature or radiance from a specific type of surface. In the present version of the SWOE CIS, research grade calculations are limited to surface temperatures from terrain elements.

This version of the SWOE CIS is a preliminary version written in the C programming language and designed to be run under the UNIX operating system. A more detailed system including a graphical User Interface System constructed with Motif™ and X Windows (Version 11 Release 4) was developed but due to difficulties in obtaining Motif™ for the target computer system, a Stardent™, delivery of the more advanced version was postponed.

6.2 Installation of the SWOE Models

This section describes how to install the SWOE thermal and cloud models, environmental databases, and Command Interface System software onto a host computer. The user is reminded that these instructions pertain only to the SWOE thermal and cloud models. The instructions for installing the SWOE radiance models are provided with the documentation that is provided with the radiance models. The SWOE thermal, cloud, and radiance models and CIS software can be operated without the SWOE scene rendering model being present on the host computer.

It is recommended that the installation of the software be performed by someone well versed with the UNIX operating system. At a minimum, however, the user installing the software needs to be familiar with the downloading of files from tape using the UNIX *tar* command, and that the user is familiar with directory read/write protections.

6.2.1 Step 1: Create a Directory for the SWOE Software

Create a directory on the host computer where all the software (source and executable) and data files will be located. This directory is known as the *installation path*. As an example for use in this users guide, this directory will be called */install_path*. Change to this directory and insure that all users of the SWOE models have read and write access to the directory.

6.2.2 Step 2: Download the Programs and Data

Copy the programs and data from the media provided using the command '*tar xvf*'. Two main subdirectories will be created automatically below */install_path*, one to hold data and one to hold the source code, *data* and *src*, respectively. Write access must be given to the *data* subdirectory for all users of the models. It is strongly recommended that users <u>not</u> make any changes to any of the data files in the */install_path/data* subdirectory. (Appendix B contains instructions on how to add data to the data subdirectory.)

6.2.3 Step 3: Enter Installation Pathname Into Header File

The installation pathname for your host computer must be entered into a header file, called *swoepath.h*, that has been provided with the CIS source code. This information is used to instruct the computer where to place the executable versions of the models after they have been compiled (see Step 4). To enter the installation pathname for your computer, move to the directory containing the CIS source code, */install_path/src/cis*. Using a standard text editor, edit the file *swoepath.h* and change the string for the *install_path* variable to your specific installation path. After saving the changes in *swoepath.h*, change back to the installation path directory, */install_path*.

6.2.4 Step 4: Create Executable Versions of Models

After the source code has been downloaded onto the host computer, the SWOE thermal and cloud model programs must be compiled and executable versions created. A UNIX "shell script," called *install*, has been provided that will compile and link the codes. To begin the compilation of the codes, type the command **install** and press RETURN. Table 14 lists the executable codes that are created and their functions. The reader is again noted that the discussion that follows pertains only to the SWOE thermal and cloud models. The radiance and scene rendering models must be installed separately using the instructions provided with these models.

The shell script *install* runs a series of "makefiles" to compile and link the CIS, the thermal, and cloud models. It is assumed that the host computer contains standard FORTRAN and C compilers.

Table 14. SWOE Executable Files Created by the *Install* Procedure

FILE	DESCRIPTION
cis_ver0	Command Interface System for Scheduling and Executing the SWOE Models
plot2d	Code for Plotting Research Grade Results
itm	SWOE Thermal Model for Calculating Surface Temperatures
lowgl	LOWTRAN Program Used by the IARTP
treedrv	Driver for TREETHERM
treethrm	TREETHERM Program for Calculating 3-D Tree Temperatures
make2c	Code for Creating MODTRAN Card 2C file
cldscene	Cloud Structure Model
cldshdow	Cloud Shadow Model

While running the *install* program, the computer will prompt you for the full path name of the installation directory where the code was installed, as shown in Figure 22. Enter the full path name of this directory and press RETURN. The computer will then check that the subdirectory for the source code (*/install_path/src*) exists, in order to verify that this is the correct installation path. The computer will then display the name of the installation path found in the file *swoepath.h*, and ask the user to verify that this variable has been changed to reflect the correct installation path. An example is shown in Figure 23.

The *install* shell script creates a subdirectory *exe*, which will contain all of the executable codes. This subdirectory is created immediately beneath the installation path directory. The *install* shell script compiles the models and moves the resulting executables versions to the *exe* directory.

Certain libraries are required in order to compile the software successfully. The standard math library, *libm.a*, is required by SWOETHRM, TREETHERM, and the cloud models. The *plot2d* program for plotting research grade results has been developed under X Windows Version 11, Revision 4 (X11R4). It uses Xlib graphics calls and requires the *libX11.a* library.

6.3 Performing a Full Scene Simulation

A full scene simulation is performed when the user desires to calculate the temperatures for a given set of terrain elements, generate the radiant field from the terrain elements, and display, or render, the resulting image for the scene. The scene simulation is performed for a given set of environmental conditions, time of day, and viewing conditions.

In order to perform a scene simulation, data must exist that physically describes

```
Install

Enter the installation directory name.  This base path name
  is used to generate full pathnames to files in the various
  subdirectories of the installation directory.
Enter installation directory name (full path): 
```

Figure 22. Prompt Displayed During the Installation Procedure Asking for the Name of the Installation Directory Path Name

```
Install

Enter the installation directory name.  This base path name
  is used to generate full pathnames to files in the various
  subdirectories of the installation directory.
Enter installation directory name (full path): /home/tosh/nlp790/swoe91


     Make sure you have edited the install_path variable
     in /home/tosh/nlp790/swoe91/src/cis/swoepath.h

     Current value:
char   *install_path = "/home/tosh/nlp790/swoe91";

     Is this value correct?  [y/n]  
```

Figure 23. Prompt Displayed Asking for a Verification of the Installation Directory Path Name Defined in the Header File, *swoepath.h*

the terrain and the environmental conditions for the desired time period. The terrain data describe where each identified feature or element in the scene is and what type of feature it is (*i.e.* bare land, land with vegetation, water, trees, target, etc.). These data must be created in advance of performing a full scene simulation. (Appendix B describes how to add data to the SWOE databases.)

In a given scene, the primary information required to calculate the required surface temperatures (land use category and slope and aspect) may be found at more than one location in a scene. Therefore, a set of unique surface material codes (USMC) are created from the overall terrain data base. The resulting USMC

data file is then used in calculating the surface temperatures. Like the main terrain data, this data file must also be provided in advance of a full scene simulation.

6.3.1 Defining Conditions

All of the data required to define simulation conditions are contained in what is termed a configuration file. The configuration file is used to provide the information required to "drive", or operate the various SWOE models. The information provided in the configuration file is used by the CIS to construct a series of additional files that are used by the individual SWOE models. These files form a set of "program drivers" that allow the user to operate any of the SWOE models in a standalone fashion. (Appendix C provides a description of the program drivers used by the CIS.)

The configuration file is given a four character "root" filename and a '*.cfg*' extension, such as '*demo.cfg*'. (The four character "root" filename is used as part of the name for all output files created by the various SWOE models.) In the present version of the CIS, configuration files are created by the user using a standard text editor. In the Motif^{TM} version of the CIS, the configuration files will be automatically created based on inputs interactively provided by the user.

Table 15 contains the format of a configuration file for a full scene simulation and an example of a configuration file is shown in Figure 24. As shown in Figure 24, the information required by the models is on the left and a brief word description of the data is on the right side of each record. A brief description of each line in the configuration file is given below.

Line #1 contains a simulation flag indicating if the configuration file is to perform a scene simulation or for research grade calculations. For a full scene simulation, this flag is set to '0'.

Line #2 contains the four character "root" filename. This filename is used as part of the name for the output files created by the SWOE models and must be identical to the four character name of the configuration file being created. For example, if the user is creating a configuration file called *demo.cfg*, the four character "root" name, *demo*, would be entered on Line #2.

Line #3 contains a flag to indicate the specific site location for the simulation. Currently, data have been provided for only one location, Hunter-Liggett. This location is specified by a location flag set to '0'. (To add more locations to the database see Appendix B.) Until more locations are added, the user would enter a '0' on Line #3.

Table 15. Description of the Configuration File for a Scene Simulation

LINE #	DESCRIPTION	RANGE
1	Simulation flag (0 = Scene Simulation, 1 = Research Grade)	0, 1
2	Four character root filename for output files	
3	Location flag (0 = Hunter-Liggett)	
4	Julian Day for simulation	1 - 365
5	Simulation Hour (local time)	0 - 23
6	Trees present flag (1 = Trees present, 0 = No Trees)	0, 1
7	Latitude for viewing conditions (degrees, minutes, seconds, hemisphere) [Example: 0 0 0.00 N]	0° - 90° 0 - 60 min 0.0 - 60.0 sec Hemisphere: N or S
8	Longitude for viewing conditions (degrees, minutes, seconds, hemisphere) [Example: 0 0 0.00 W]	0° - 180° 0 - 60 min 0.0 - 60.0 sec Hemisphere: W or E
9	Altitude for viewing conditions (meters AGL)	0.0 - 30,000.0 m
10	Yaw (degrees) for viewing conditions (0.0° = E, 90.0° = N, 180.0° = W, 270.0° = S)	0.0° - 360.0°
11	Pitch (degrees) for viewing conditions (Positive = down, Negative = up)	−90.0° - +90.0°
12	Roll (degrees) for viewing conditions (Positive = right, Negative = left)	−180.0° - +180.0°
13	Sensor bandpass start and stop wavelengths; if both set to 0.0 the user must enter a filter name on the next line [Example: 8.00 12.00]	0.2 - 25.0 μm
14	User-defined filter name to be used if wavelengths set to 0.0 on Line 13	
15	Total number of targets in the scene	0 - 99
Lines 16-20 are repeated for each target:		
16	Name of the target configuration file	
17	Target heading (degrees) (0.0° = N, 90.0° = E, 180.0° = S, 270.0° = W)	0.0° - 360.0°
18	Target altitude (meters AGL)	0.0 - 30,000.0 m
19	Target Latitude (degrees, minutes, seconds, hemisphere) [Example: 0 0 0.00 N]	0° - 90° 0 - 60 min 0.0 - 60.0 sec Hemisphere: N or S
20	Target Longitude (degrees, minutes, seconds, hemisphere) [Example: 0 0 0.00 W]	0° - 180° 0 - 60 min 0.0 - 60.0 sec Hemisphere: W or E

```
              0             0 = Scene Simulation, 1 = Research Grade
           scen             Root filename for output files
              0             Location:  Hunter-Liggett
             11             Julian Day for simulation
             12             Simulation Hour
              1             1 = Trees present, 0 = NO Trees
 35 55 12.00  N             Latitude: degrees, minutes, seconds, hemi
121 15 36.00  W             Longitude: degrees, minutes, seconds, hemi
      1000.0000             Altitude (meters)
         90.000             Yaw (degrees)
         30.000             Pitch (degrees)
          1.000             Roll (degrees)
   8.00   12.00             Lambda 1,  Lambda2
NONE                                              Filter name
              1             Total Number of Targets
        m60.cfg             Target configuration file
          135.0             Target heading
            2.0             Target altitude
 35 55 12.00  N             Target Latitude: degrees, minutes, seconds, hemi
121 15 36.00  W             Target Longitude: degrees, minutes, seconds, hemi
```

Figure 24. Example of a Configuration File for a Full Scene Simulation

Line #4 contains the Julian day for the simulation. Meteorological data must be available to the program for the Julian day specified for the location chosen on Line #3. Table 4 lists the Julian days for which meteorological data have been provided for the Hunter-Liggett location. (To add more Julian days to the database see Appendix B.)

Line #5 contains the local time for which the simulation will be performed. This number can be any integer value between 0 and 23.

Line #6 contains a flag to indicate whether or not trees will be included in the scene. This flag is set to '1' if trees are present, or '0' if no trees are present in the scene. (Because the calculation of tree temperatures and radiances is computationally intensive, the user is given this option to not include trees in case the user simply wishes to display a quick view of the ground terrain.) The total number and location of the trees in the scene are defined for each location by a tree location data file named (*tsites.ll*) that is described in Appendix B.

Lines 7-12 define the viewing conditions for the radiance calculations and scene rendering. The latitude and longitude of the viewer are entered in degrees, minutes, seconds and hemisphere, on Lines 7 and 8. Degrees and minutes are entered as integers, seconds as a real number and the hemisphere as a single letter, either *N, S, W,* or *E.* The degrees, minutes, seconds and hemisphere

for latitude or longitude, are entered on a single line, separated by spaces. For example, a latitude of 0 degrees, 0 minutes, 0.0 seconds and northern hemisphere would be entered as '*0 0 0.0 N*' on Line #7. The altitude in meters above ground level (AGL) is entered as a real number on Line #9. The yaw, pitch, and roll are entered in degrees as real numbers on Lines 10, 11, and 12.

Lines 13 and 14 define the sensor bandpass for the radiance calculations. For a "tophat" response function, the user enters a starting and stopping wavelength on Line #13. These wavelengths are entered as real numbers and are separated by a space. For a user-defined sensor bandpass, the user enters '0.0 0.0' for the start and stop wavelengths on Line #13 and a filter name (up to 40 characters) on Line #14. This filter name is defined in the data file *filters.dat* located in the directory */install_path/data/radiance.* (This file is described in more detail in the users manual for the radiance program.) Briefly, for each user-defined filter, the file, *filters.dat*, contains the filter name which is entered in the configuration file, followed by the number of wavenumbers that define the filter and then the corresponding wavenumber and spectral response.

Line #15 contains the total number of targets in the scene. This number can be any integer value between 0 and 99.

Lines 16-20 are repeated for each target in the scene. The user enters the name of the target configuration file on Line #16. The target configuration file defines the type of target being considered. It contains three target data filenames for the wireframe data, the temperature data, and the thermal filename. The target configuration file and the target data files should be located in the directory, */install_path/data/target.* The target location is then entered on Lines 17-20. The user must specify the target heading, altitude in meters above ground level, and the latitude and longitude in degrees, minutes, seconds, and hemisphere.

6.3.2 Executing the CIS

Once the user has created the configuration file defining the conditions to use for a full scene simulation, the CIS is called to begin the simulation by typing the command 'cis_ver0' and pressing RETURN. (The user must be in the directory containing the executable codes or have a path declared that includes the executable codes.) The CIS will begin the simulation by prompting for the four character root name, as shown in Figure 25. Type in the four character name and press RETURN. (The configuration file with this "root" name and a '*.cfg*' extension must exist in the user's local directory.) The CIS will read in the configuration file and then present the user with the list of available options for a full scene simulation, as shown in Figure 26. These options are:

- Calculate Temperatures
- Calculate Radiances
- Scene Render
- Exit

6.3.2.1 Performing Temperature Calculations

To perform temperature calculations, type '**1**' at the prompt to 'Enter Option', as shown in Figure 26, and press RETURN. The CIS checks for temperature files that may already exist with the four character "root" filename entered by the user. If temperature files exist with the same name, the CIS will warn the user that these files will be overwritten and prompt the user to confirm that it is OK to overwrite the files, as shown in Figure 27. If the user enters '**n**' to not overwrite the files, the simulation will be aborted and the user will be returned to the main command line prompt. To continue with the simulation and overwrite any previously calculated files, the user enters '**y**' and presses RETURN.

The CIS begins the simulation by calling the SWOE thermal models. Temperatures for the terrain elements specified by the USMC file are calculated first. This is followed by the execution of TREETHERM, if trees are present in the scene. Tree temperatures are calculated for two different types of trees with four different rotations relative to north (0°, 90°, 180°, and 270°).

If errors occur in the execution of any of the models, the CIS displays an error message to the user and the simulation is aborted. The user is then returned to the command line prompt.

A number of output files containing temperatures are produced by the SWOE thermal models. Table 16 lists the output files produced by the SWOE thermal models and the naming convention used. When the temperature calculations have completed successfully, the option menu for scene simulations, shown in Figure 26, is redisplayed to the user.

6.3.2.2 Performing Radiance Calculations

To perform radiance calculations, enter '**2**' at the 'Enter Option' prompt shown in Figure 26 and press RETURN. In order to calculate radiances, temperature calculations **must** be performed first. The CIS checks that the appropriate temperature files exist before starting the radiance calculations. If they do not, an error message will be displayed to the user, as shown in Figure 28, and the user is returned to the main options menu. If the temperature output files exist, the CIS executes the radiance driver to calculate radiances. The radiance driver is called automatically by the CIS several times. The first time is for calculation of the terrain radiances for each USMC. If trees are present in the scene, the CIS then calls the radiance

```
cis_ver0

Enter ROOT output filename (max 4 characters):
```

Figure 25. Screen Prompting for the Four Character Root Name

```
cis_ver0

Enter ROOT output filename (max 4 characters):  demo

               ##############################
                    OPTION MENU

                1 = Calculate Temperatures
                2 = Calculate Radiances
                3 = Scene Render

                0 = EXIT
               ##############################

               Enter Option:
```

Figure 26. CIS Options Available for a Full SWOE Scene Simulation

Table 16. Output Files From the Temperature Calculations for a Scene Simulation. The term <root> refers to the four character "root" filename entered by the user

FILE	DESCRIPTION
<root>.tem	ITM output file containing the USMC's for the scene location with fraction of direct solar flux and the surface temperature at the simulation time appended to each line
<root>_day.tem	ITM output file containing surface temperatures for each USMC at all times in the meteorological data file for the chosen day.
<root>_rg.tem	A dummy ITM output file
e<root><type>.<ext>	Echo file* produced by TREETHERM for: <type> = 't1', tree type #1 <type> = 't2', tree type #2 and for: <ext> = '000', an orientation of 0° <ext> = '090', an orientation of 90° <ext> = '180', an orientation of 180° <ext> = '270', an orientation of 270°
o<root><type>.<ext>	Output file produced by TREETHERM for: <type> = 't1', tree type #1 <type> = 't2', tree type #2 and for: <ext> = '000', an orientation of 0° <ext> = '090', an orientation of 90° <ext> = '180', an orientation of 180° <ext> = '270', an orientation of 270°

* - The echo file prints out all of the input conditions used by TREETHERM for a given calculation

driver twice, once for each tree type. Finally, the CIS calls the radiance driver once for each target in the scene.

If errors occur in the execution of the radiance driver, the CIS displays an error message to the user and the simulation is aborted. The user is returned to the command line prompt.

When the radiance calculations have completed successfully, the option menu for scene simulations, shown in Figure 26, is redisplayed to the user. A description of the radiance calculations output files and the naming conventions used is given in Table 17.

```
                              cis_ver0
                 OPTION MENU

             1 = Calculate Temperatures
             2 = Calculate Radiances
             3 = Scene Render

             0 = EXIT
            ##############################

            Enter Option:  1

------------------------------------------------
           WARNING
Output data files with the root filename,
demo, already EXIST and will be OVERWRITTEN!
------------------------------------------------
      OK to OVERWRITE? [y/n]
```

Figure 27. CIS Warning That Files will be Overwritten

```
                              cis_ver0
               Enter Option:  2

*******************************************************
 ERROR: Terrain temperature output file does not exist!
        Execute temperature calculations FIRST!
*******************************************************


               ##############################
                    OPTION MENU

                 1 = Calculate Temperatures
                 2 = Calculate Radiances
                 3 = Scene Render

                 0 = EXIT
               ##############################

               Enter Option:
```

Figure 28. Error Message Displayed by the CIS Warning That Temperature Files Must Exist Before Radiances can be Calculated During a Scene Simulation

Table 17. Output Files Produced During the Radiance Calculations. The term <root> refers to the four character "root" filename entered by the user

FILE	DESCRIPTION
<root>.bct	Terrain radiance output file
<root><type><o#><q#>.<ext>	Tree radiance output file, for: <type> = 't1', tree type #1 <type> = 't2', tree type #2 and for: <o#> = '0', an orientation of 0° <o#> = '1', an orientation of 90° <o#> = '2', an orientation of 180° <o#> = '3', an orientation of 270° and for: <q#> = '0', quadrant zero and for: <ext> = 'bcp', Boeing CIG polygon file <ext> = 'bcv', Boeing CIG vertex file
<root>**tg**<target#>.<ext>	Target radiance output file, where: <target#> = the target number ('0' to '99') and: <ext> = 'bcp', Boeing CIG polygon file <ext> = 'bcv', Boeing CIG vertex file

6.3.2.3 Performing Scene Rendering

To perform scene rendering, enter '3' at the 'Enter Option' prompt shown in Figure 26 and press RETURN. In order to render a scene, radiance calculations **must** be performed first. The CIS checks that the appropriate radiance files exist before starting the scene rendering. If they do not. an error message will be displayed to the user as shown in Figure 29 and the user is returned to the options menu. If the radiance output files exist, the CIS executes the scene rendering driver. This driver prompts the user for further information required to render a scene. See the scene rendering manual for more information.

6.3.2.4 Exiting the CIS

To exit the CIS, type '0' at the option menu displayed in Figure 26 and press RETURN. Upon entering '0', the user exits the CIS and is returned to the main command line prompt.

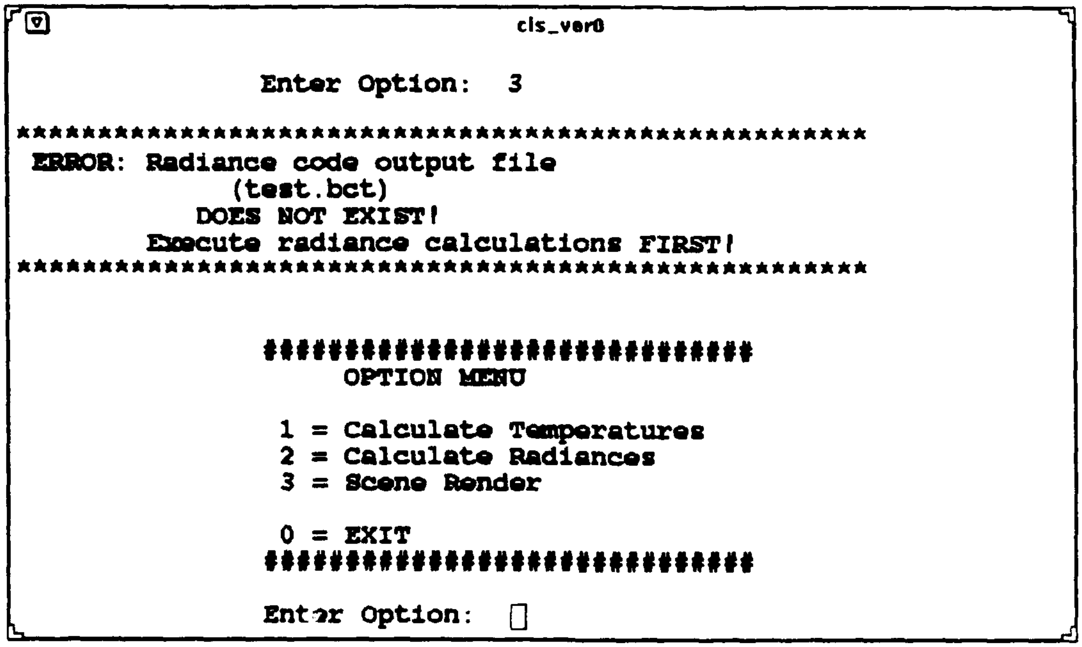


Figure 29. Error Message Displayed by the CIS Warning That Radiance Files Must Exist Before Scene Rendering can be Performed During a Scene Simulation

6.4 Performing Research Grade Calculations

Research grade calculations are performed when the user wishes to calculate temperatures for a single set of terrain conditions. This option is intended for use mainly for when the user wants to make a more detailed analysis of a surface (*i.e.*, one surface material code with specific slope and aspect angles) can be made. The user must still choose a location and Julian day, in order to define the meteorological conditions that will be used. A specific surface material code is then specified and the temperatures are calculated for each time in the meteorological data file. On-screen plots of temperature versus time are also available.

6.4.1 Defining Conditions

Table 18 contains the format of a configuration file that is used for research grade calculations and Figure 30 shows an example of a configuration file. A brief description of each line in the configuration file is given here.

Line #1 contains a flag indicating if this configuration file is being used for a scene simulation or research grade calculations. For research grade calculations, this flag is set to '1'.

Line #2 contains the four character "root" filename. This filename is used as part of the prefix for all output files created by the models and should be

Table 18. Overall Configuration File for Research Grade Calculations

LINE #	DESCRIPTION	RANGE
1	Simulation flag (0 = Scene Simulation, 1 = Research Grade)	0, 1
2	Four character root filename for output files	
3	Location flag (0 = Hunter-Liggett)	
4	Julian Day for simulation	1 - 365
5	Type of Surface Layer 0 = Bare 1 = Snow 2 = Low Vegetation 3 = Medium Vegetation 4 = High Vegetation 5 = Deciduous Forest 6 = Coniferous Forest 7 = Water	0 - 7
6	Type of Topsoil Surface 0 = Sand 1 = Silt 2 = Clay	0 - 2
7	Type of Subsoil Surface 0 = Sand 1 = Silt 2 = Clay	0 - 2
8	Slope Angle of the Single Surface Type (degrees)	0° - 90°
9	Aspect Angle of Single Surface Type (degrees)	0° - 180°

```
   1          0 = Scene Simulation, 1 = Research Grade
rgrd          Root filename for output files
   0          Location:  Hunter-Liggett
 102          Julian Day for simulation
   0          Surface: Bare
   0          Top Soil: SAND
   0          Sub Soil: SAND
   0          Slope Angle (deg)
   0          Aspect Angle (deg)
```

Figure 30. Example of a Configuration File for Research Grade Calculations

identical to the four character prefix of the configuration file being created. For example, if the user is creating a configuration file called *demo.cfg*, the four character "root" name, *demo*, would be entered on Line #2.

Line #3 contains a location flag to indicate the location for the calculation. Currently, data have been provided for only one location, Hunter-Liggett. This location is specified by the location flag '0'. (To add more locations to the database see Appendix B.) Until more locations are added to the database, the user should only enter a '0' on Line #3.

Line #4 contains the Julian day for the simulation. Meteorological data must be available for the Julian day specified for the location chosen on Line #3. (To add more Julian days to the database see Appendix B.)

Lines 5-9 define the surface conditions to be used for the research grade calculations. The user must enter the type of surface layer, topsoil, and subsoil via the flags defined in Table 18 on Lines 5-7. The slope and aspect angles are then entered as integers on Lines 8 and 9, respectively,

If the user chooses 'Snow' as the surface layer by entering '1' on Line #5, the value of the topsoil layer is ignored by the CIS. The topsoil layer is set internally to 'Snow'. The CIS will only read the subsoil layer if the surface layer is 'Snow'.

If the user chooses 'Water' as the surface layer by entering '1' on Line #5, the CIS ignores the top and subsoil layers. In addition, when the surface layer is set to 'Water', the slope and aspect angles are internally set to zero.

6.4.2 Executing the CIS

Once the user has created a configuration file defining the conditions to use for research grade analysis, the CIS is executed by typing the command **cis_ver0** at the command line prompt and pressing RETURN. Again, it is assumed that the user is either in the subdirectory containing the executable code or has declared a path with access to the executable codes.) The CIS prompts the user for the four character "root" filename of the configuration file, as shown in Figure 25. The configuration file with this "root" name and a '*.cfg*' extension must exist in the user's local directory. The CIS reads in the configuration file and then presents the user with the available options for research grade calculations, as shown in Figure 31. These options are:

- Calculate Temperatures
- Plot Research Grade Results
- Exit

```
cis_ver0

Enter ROOT output filename (max 4 characters):  rgrd

               ###################################
                    OPTION MENU

                1 = Calculate Temperatures
                2 = Plot Research Grade Results

                0 = EXIT
               ###################################

               Enter Option:  []
```

Figure 31. CIS Options Available for Research Grade Calculations

6.4.2.1 Performing Temperature Calculations

To perform temperature calculations, the user enters '**1**' at the prompt to 'Enter Option' shown in Figure 31. The CIS checks for temperature files that may already exist with the four character "root" filename entered by the user. If such files exist, the CIS will warn the user that these files will be overwritten and prompt the user to overwrite the files. If the user enters '**n**' to not overwrite the files, the simulation will be aborted and the user will be returned to the command line prompt. To continue with the simulation and overwrite any previously calculated files, the user enters '**y**' and presses RETURN.

The CIS immediately starts execution of the SWOE thermal models. Temperatures are calculated, using the ITM, for the single polygon specified in the configuration file.

If errors occur in the execution of the ITM, the CIS displays an error message to the user and the simulation is aborted. The user is returned to the command line prompt.

When the temperature calculations have completed successfully, the option menu for research grade calculations, shown in Figure 31, is redisplayed to the user. A description of the temperature calculations output files and the naming conventions used is given in Table 19.

Table 19. Output Files Produced for a Research Grade Calculation. (The term <root> refers to the four character "root" name entered by the user)

FILE	DESCRIPTION
<root>.tem	ITM output file containing the USMC for the single polygon with fraction of direct solar flux and the the top layer surface temperature at time zero
<root>_day.tem	ITM output file containing the top layer surface temperatures for the specified surface conditions for the times for the selected day chosen.
<root>_rg.tem	ITM output file containing the temperatures used for plotting.

6.4.2.2 Plotting Research Grade Results

The research grade temperatures can be plotted as a function of time by selecting option 2 from the menu displayed in Figure 31. To do this, type '**2**' and press RETURN. Note that the user must be running the CIS in an X Windows environment in order to produce the plots. This option executes the *plot2d* program which plots the output file, <root>_rg.tem. Note that the user can plot results from previous sessions with the CIS, along with plotting results that might have been just calculated. Examples of plots are shown in Figures 32 and 33 for a bare surface layer and a deciduous forest, respectively. When done viewing the plots, the user moves the cursor into the window containing the plot and clicks the select button on the mouse. The plot window will disappear and the research grade option menu will be displayed to the user.

6.4.2.3 Exiting the CIS

To exit the CIS, the user should type a '**0**' for the option from the menu displayed in Figure 31 and press RETURN. Upon entering '0', the user is returned to the main command line prompt.

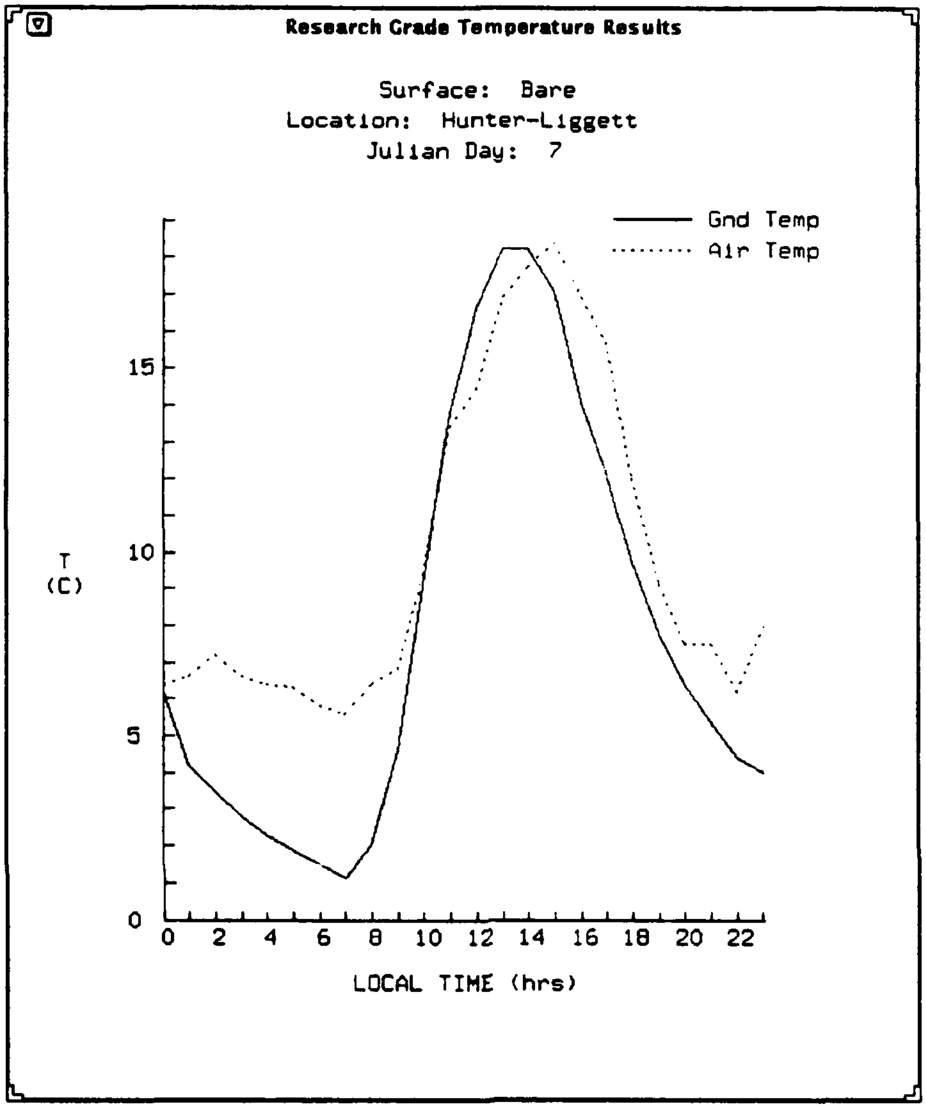


Figure 32. Example of a Plot of Temperatures as a Function of Time for a Bare Surface Produced From the Research Grade Option With the CIS

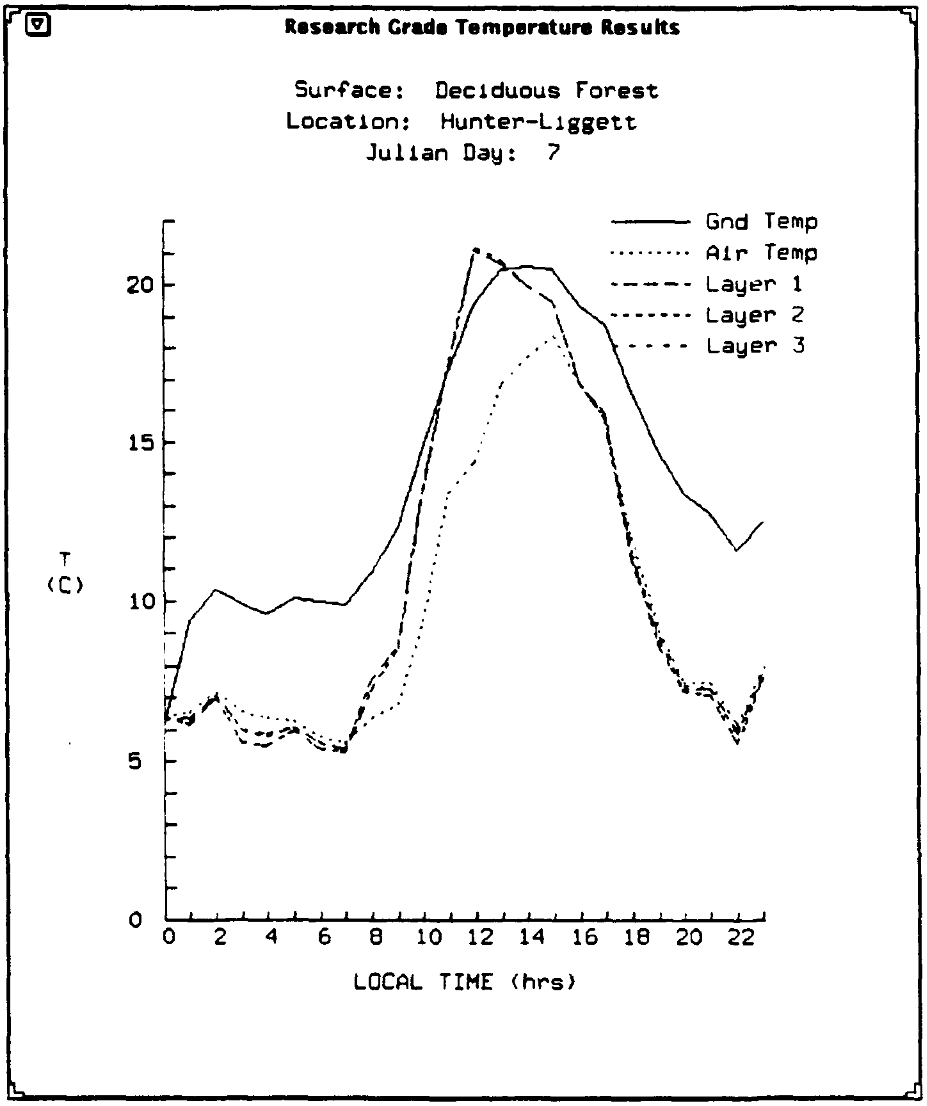


Figure 33. Example of a Plot of Temperatures as a Function of Time for a Surface With a Deciduous Forest Produced From the Research Grade Calculation Option with the CIS

7 SUMMARY AND RECOMMENDATIONS FOR FUTURE WORK

The Balanced Technology Initiative on Smart Weapons Operability Enhancement (BTI/SWOE) has as a goal to model the radiant field from complex natural backgrounds. During the three years of the program, the calculation of these radiant fields has evolved to produce a process, known as the SWOE Process, that will permit a smart weapons designer or tester to:

- Obtain and specify the data required to describe the physical characteristics and the environmental conditions of a scene
- Model the physical processes controlling the generation of the radiant field
- Display and analyze the results of the simulated scene.

SPARTA has had the responsibility for the development and integration of the SWOE thermal models into the SWOE Process. In addition, SPARTA has had the responsibility for the design and development of the Command Interface System (CIS) for the control and operation of the SWOE models and the User Interface System (UIS) to permit the user to access the SWOE databases and review results from the models.

7.1 Summary

7.1.1 Redesign of the SWOE Physics Data Files

The databases used previously in the SWOE thermal models were to a large extent, intimidating to the user. A review of all of the physics databases was performed and the structure of the databases reformulated. Parameters that are typically only used for detailed sensitivity studies were assembled into a "research grade" database and others were "hardwired" into the physics models. The remaining data were assembled into a consistent, easy-to-use database.

The environmental data were assembled into a database based on standard surface weather data. A database of environmental data was assembled for Fort Hunter-Ligget, California. The database consisted of four, seven day periods, one for each season.

A library of surface material properties was created to cover the expected range of "typical" surface conditions. These values were hardwired into the thermal models. In addition, seasonally dependent values for some of the vegetative material properties were obtained and added to the models.

7.1.2 Enhancements to the SWOE Thermal Models

A number of enhancements to the SWOE thermal models were made. The enhancements represent the filling in of gaps in the models, improvements, or the correction of errors.

The 3-D tree thermal model, TREETHERM, was modified to bring it under the umbrella of the SWOE CIS. Instead of being run as a standalone model. TREETHERM can now be run automatically by the CIS.

A second database for a smaller tree was assembled and added to the TREE-THERM repertoire. The two trees now allow the user to provide a greater degree of variability in a given scene simulation. During a scene simulation, temperatures for the two trees are calculated at four orientations, relative to north, giving rise to eight sets of tree temperatures that can be placed throughout a scene.

7.1.3 Development of the IARTP

An Interim Atmospheric Radiative Transfer Package (IARTP) was developed to calculate the solar and longwave fluxes required by the SWOE physics models. The IARTP was developed on an interim basis in response to delays in the delivery of the full SWOE atmospheric radiative transfer package. The IARTP is based on LOWTRAN7 with provisions to account for partly clear or cloudy conditions.

7.1.4 Development of the SWOE Command Interface System

A Command Interface System (CIS) has been developed to aid the user in performing calculations with the SWOE models. The SWOE CIS is designed to assist the user in creating the necessary input files to run the SWOE models.

The version of the SWOE CIS delivered is a preliminary version written in the C programming languaage. A more detailed version based on X Windows and OSF Motif^{TM} was developed, but due to difficulties in obtaining Motif^{TM} for the target computer system, a Stardent^{TM}, delivery of the more advanced version was postponed.

7.2 Recommendations for Future Work

7.2.1 Development of a Full Atmospheric Radiative Transfer Package

The IARTP needs to be replaced by the full SWOE Atmospheric Radiative Transfer Package (SARTP). The SARTP would be coupled to the SWOE cloud models, thereby providing an increased ability to simulate scenes involving clouds in the field of view.

7.2.2 Development of the Full X Windows Version of the SWOE UIS

The simple, C language versions of the CIS and UIS, were developed as stopgap measures in order that the program's deliverables could be delivered on time. With the SWOE program slated to enter the Joint Test and Evaluation arena, the full X Windows version should be completed. With all of the SWOE models residing on a single computer platform, the preliminary X Windows version of the UIS should be extended to cover the radiance and scene rendering models.

In addition, the option of performing "research grade" calculations with the radiance models should be provided. This would entail the development of a series of plotting and/or analysis options for the radiance models. These options, when combined with those currently available with the thermal models would give the user a powerful set of tools for modeling and understanding the impact of environmental conditions on smart weapons systems.

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Appendix A

Meteorological Data for Fort Hunter-Liggett, California

This Appendix lists the meteorological data that were provided for Fort Hunter-Liggett, California. Table A-1 gives a summary of the weather conditions in the data files. The data are grouped into seasons. Figure A-1 lists the data for winter, Figure A-2 the data for spring, Figure A-3 the data for summer, and Figure A-4 lists the data for fall.

Table A-1. Summary of Weather Conditions in the Fort Hunter-Liggett Surface Weather Data Files

JULIAN DAY	DATE DATA TAKEN	SEASON	COMMENTS
7	7 Jan 1990	Winter	Clear Skies, Visibilities Missing
8	8 Jan 1990	Winter	Clouds 0600 - 1600 LST
9	9 Jan 1990	Winter	Fog 0600 - 0900 LST, Some Visibilities Missing
10	10 Jan 1990	Winter	Clouds 0600 - 1600 LST
11	11 Jan 1990	Winter	Overcast 0500 - 1600 LST
12	12 Jan 1990	Winter	Cloudy Skies 0600 - 1600 LST, Precipitation 0300 - 1800 LST, Some Visibilities Missing
13	13 Jan 1990	Winter	Precipitation Reported, No Clouds Reported, Visibilities Missing
101	10 April 1988	Spring	Clear Skies, Visibilities Missing
102	11 April 1988	Spring	Clouds 0500 - 1400 LST
103	12 April 1988	Spring	Clouds 0500 - 1500 LST
104	13 April 1988	Spring	Clouds 0500 - 1500 LST
105	14 April 1988	Spring	Clouds 0500 - 1500 LST, Trace of Precipitation 0500 - 1000 LST
106	15 April 1988	Spring	Clouds 0500 - 1500 LST
107	16 April 1988	Spring	Clear Skies, Visibilities Missing
197	16 July 1989	Summer	Clear Skies, Visibilities Missing
198	17 July 1989	Summer	Clear Skies
199	18 July 1989	Summer	Clear Skies
200	19 July 1989	Summer	Clouds 1300 - 1600 LST
201	20 July 1989	Summer	Clouds 0500 - 1600 LST
202	21 July 1989	Summer	Clouds 0500 - 1500 LST
203	22 July 1989	Summer	Clear Skies, Visibilities Missing
287	14 October 1990	Fall	Clear Skies, Visibilities Missing
288	15 October 1990	Fall	Clouds 1100 - 1500 LST
289	16 October 1990	Fall	Clouds 0600 - 1400 LST
290	17 October 1990	Fall	Clouds 0600 - 1500 LST
291	18 October 1990	Fall	Clouds 0600 - 1500 LST
292	19 October 1990	Fall	Clouds 0600 - 1100 LST
293	20 October 1990	Fall	Clear Skies, Visibilities Missing

(a.) Data File: *hl00790.met*

Fort Hunter-Liggett, CA 7 Jan 1990 Winter Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 1

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
7	0 0	990.5	6.4	92.0	0.7	338.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	1 0	990.3	6.6	93.0	0.8	295.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	2 0	989.8	7.2	93.0	1.4	88.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	3 0	990.1	6.6	91.0	0.2	20.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	4 0	989.7	6.4	93.0	0.3	11.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	5 0	989.7	6.3	93.0	0.9	240.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	6 0	990.3	5.8	94.0	0.8	309.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	7 0	990.8	5.6	94.0	0.9	35.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	8 0	988.3	6.4	96.0	0.5	330.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	9 0	990.7	6.8	93.0	1.1	314.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	10 0	992.1	9.4	83.0	0.9	113.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	11 0	992.0	13.4	67.0	1.1	137.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	12 0	990.4	14.4	60.0	0.7	205.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	13 0	989.4	16.9	49.0	1.2	196.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	14 0	988.5	17.7	48.0	1.6	221.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	15 0	988.5	18.4	50.0	1.9	76.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	16 0	988.7	16.9	54.0	3.0	53.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	17 0	988.5	15.7	59.0	0.5	158.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	18 0	988.8	12.0	72.0	0.7	348.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	19 0	989.2	9.1	86.0	0.8	325.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	20 0	989.7	7.5	90.0	1.1	316.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	21 0	989.6	7.5	91.0	0.8	309.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	22 0	989.9	6.2	93.0	0.5	341.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
7	23 0	990.1	8.0	96.0	1.0	344.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0

(b.) Data File: *hl00890.met*

Fort Hunter-Liggett, CA 8 Jan 1990 Winter Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 1

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
8	000	989.4	7.1	96.0	0.9	316.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	100	989.1	7.4	97.0	1.2	331.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	200	989.1	7.5	97.0	1.0	332.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	300	988.8	7.4	97.0	0.8	23.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	400	988.8	5.8	97.0	1.1	292.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	500	988.2	7.3	98.0	0.6	326.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	600	988.5	6.9	98.0	0.9	335.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	700	988.5	5.9	98.0	0.5	343.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	800	988.8	8.1	98.0	0.4	324.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	900	989.0	7.2	93.0	0.6	192.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	1000	989.0	10.1	88.0	0.9	164.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	1100	988.5	14.6	74.0	0.7	167.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	1200	987.2	16.2	73.0	1.2	173.0	24.0	1	0.0	0	0.0	1	0.0	0	0.0	0
8	1300	985.8	17.5	71.0	1.2	180.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	1400	984.8	18.8	67.0	1.7	180.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	1500	984.5	19.6	63.0	1.5	182.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	1600	984.3	20.2	61.0	0.8	217.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
8	1700	984.1	18.1	64.0	0.8	67.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	1800	984.3	13.3	78.0	1.1	267.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	1900	984.9	9.8	90.0	1.1	330.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	2000	985.5	9.2	94.0	0.8	327.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	2100	985.8	9.1	95.0	0.8	308.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	2200	986.1	8.7	96.0	1.0	330.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
8	2300	986.4	9.9	97.0	0.8	339.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0

Figure A-1. Meteorological Data for Winter at Fort Hunter-Liggett, California, (a.) 7 Jan 1990, (b.) 8 Jan 1990,

(c.) Data File: *hl00990.met*

Fort Hunter-Liggett, CA 9 Jan 1990 Winter Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 1

		Press	Temp	RH	Wd Spd	Dirct	Vis	Aer	Precip		Cloud Data					
Day	Time	(mb)	(C)	(%)	(m/s)	(deg)	(km)	H	(mm/hr)	P	Amt	L	Amt	M	Amt	H
9	0 0	986.4	8.7	98.0	0.8	335.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	1 0	986.2	8.5	98.0	0.9	351.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	2 0	986.3	7.9	98.0	1.0	330.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	3 0	986.2	7.7	99.0	1.0	333.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	4 0	985.8	7.4	99.0	0.9	339.0	16.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	5 0	985.5	6.9	99.0	0.5	174.0	16.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	6 0	985.7	5.0	99.0	0.3	999.0	16.0	9	0.00	0	1.0	1	0.0	0	0.0	0
9	7 0	986.3	4.3	100.0	0.4	128.0	8.0	9	0.00	0	1.0	1	0.0	0	0.0	0
9	8 0	987.0	4.5	100.0	1.0	318.0	8.0	9	0.00	0	1.0	1	0.0	0	0.0	0
9	9 0	987.4	6.9	100.0	0.7	305.0	8.0	9	0.00	0	1.0	1	0.0	0	0.0	0
9	10 0	987.1	11.9	98.0	0.5	310.0	16.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	11 0	986.5	11.6	94.0	0.9	142.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	12 0	985.2	16.2	76.0	1.0	134.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	13 0	983.9	17.2	70.0	1.3	152.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	14 0	983.2	20.2	54.0	1.1	115.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	15 0	982.9	21.2	50.0	1.0	160.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	16 0	982.6	20.7	50.0	1.4	162.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	17 0	982.4	18.2	58.0	0.3	224.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	18 0	982.8	10.5	79.0	1.5	325.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	19 0	983.1	8.3	83.0	0.8	320.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	20 0	983.7	6.7	89.0	1.2	319.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	21 0	983.9	6.6	89.0	1.0	341.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	22 0	984.3	5.8	91.0	0.7	355.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
9	23 0	984.7	4.7	91.0	0.6	288.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0

(d.) Data File: *hl01090.met*

Fort Hunter-Liggett, CA 10 Jan 1990 Winter Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 1

		Press	Temp	RH	Wd Spd	Dirct	Vis	Aer	Precip		Cloud Data					
Day	Time	(mb)	(C)	(%)	(m/s)	(deg)	(km)	H	(mm/hr)	P	Amt	L	Amt	M	Amt	H
10	000	984.4	4.7	93.0	1.0	345.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
10	100	984.0	3.4	94.0	0.6	0.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
10	200	983.9	2.3	95.0	0.4	314.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
10	300	983.7	3.5	96.0	0.4	310.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
10	400	983.4	3.5	97.0	0.7	307.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
10	500	983.6	2.2	97.0	0.7	313.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
10	600	983.3	2.4	97.0	0.4	344.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
10	700	983.6	2.5	97.0	0.5	305.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
10	800	983.6	4.5	96.0	0.6	2.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
10	900	983.8	7.3	86.0	0.3	185.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
10	1000	983.9	12.0	69.0	0.3	125.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
10	1100	983.7	14.4	58.0	1.1	165.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
10	1200	982.3	18.3	45.0	0.8	193.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
10	1300	981.2	21.3	39.0	1.0	163.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
10	1400	980.4	22.4	36.0	1.2	188.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
10	1500	979.9	23.8	33.0	1.1	162.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
10	1600	979.9	23.4	37.0	1.1	152.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
10	1700	979.7	20.2	41.0	1.1	101.0	24.0	1	0.0	0	0.5	1	0.0	0	0.0	0
10	1800	979.7	12.8	64.0	1.3	339.0	24.0	1	0.0	0	0.5	1	0.0	0	0.0	0
10	1900	980.0	10.8	70.0	1.3	339.0	24.0	1	0.0	0	0.5	1	0.0	0	0.0	0
10	2000	980.2	8.9	75.0	1.2	352.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
10	2100	980.5	8.0	76.0	0.8	16.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
10	2200	980.9	6.7	78.0	0.9	327.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
10	2300	981.2	5.2	84.0	1.0	327.0	24.0	1	0.0	0	1.0	1	0.0	0	0.0	0

Figure A-1. (Continued) (c.) 9 Jan 1990, (d.) 10 Jan 1990,

(e.) Data File *hl01190.met*

Fort Hunter-Liggett, CA 11 Jan 1990 Winter Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 1

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
11	0 0	980.5	4.8	86.0	1.0	317.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	1 0	980.1	5.1	83.0	1.0	341.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	2 0	980.1	4.9	83.0	0.5	326.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	3 0	980.2	3.9	86.0	0.7	328.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	4 0	980.2	4.1	86.0	0.8	15.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	5 0	980.6	2.9	91.0	0.5	332.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	6 0	980.4	2.3	93.0	1.3	305.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	7 0	980.3	1.9	94.0	1.0	330.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	8 0	980.8	2.5	94.0	0.5	261.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	9 0	981.3	6.2	85.0	1.0	317.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	10 0	981.1	11.5	70.0	0.8	226.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	11 0	980.6	16.7	55.0	0.8	151.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	12 0	979.4	17.8	55.0	1.4	107.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	13 0	978.2	19.3	52.0	1.3	138.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	14 0	977.3	19.8	49.0	2.3	133.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	15 0	976.7	21.1	44.0	2.0	130.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	16 0	976.9	19.3	36.0	3.9	209.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	17 0	976.9	17.4	39.0	2.0	192.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	18 0	977.6	14.0	57.0	2.7	125.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	19 0	977.9	12.2	73.0	2.8	119.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	20 0	978.1	12.3	77.0	1.7	182.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	21 0	978.4	11.8	81.0	2.9	154.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	22 0	978.8	11.5	82.0	2.7	154.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
11	23 0	978.9	11.4	84.0	1.8	138.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0

(f.) Data File: *hl01290.met*

Fort Hunter-Liggett, CA 12 Jan 1990 Winter Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 1

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
12	000	978.6	10.2	88.0	0.4	334.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
12	100	978.3	10.9	90.0	2.9	123.0	20.0	1	0.00	0	1.0	1	0.0	0	0.0	0
12	200	977.9	12.8	95.0	2.0	136.0	18.0	1	0.00	0	1.0	1	0.0	0	0.0	0
12	300	977.5	15.3	96.0	1.9	136.0	16.0	1	0.25	1	1.0	1	0.0	0	0.0	0
12	400	976.7	16.1	97.0	2.4	126.0	14.0	1	1.27	1	1.0	1	0.0	0	0.0	0
12	500	976.3	16.5	98.0	2.7	142.0	12.0	1	0.76	1	1.0	1	0.0	0	0.0	0
12	600	976.4	17.1	97.0	4.0	133.0	11.0	1	1.78	1	1.0	1	0.0	0	0.0	0
12	700	976.3	17.4	97.0	4.8	127.0	8.0	1	1.02	1	1.0	1	0.0	0	0.0	0
12	800	976.4	18.0	96.0	4.3	127.0	4.0	1	2.03	1	1.0	1	0.0	0	0.0	0
12	900	977.1	18.6	96.0	4.7	125.0	8.0	1	2.79	1	0.8	1	0.0	0	0.0	0
12	1000	977.7	15.3	93.0	4.9	153.0	11.0	1	0.51	1	0.8	1	0.0	0	0.0	0
12	1100	977.6	14.9	94.0	5.5	153.0	4.0	1	0.51	1	0.8	1	0.0	0	0.0	0
12	1200	976.4	15.0	94.0	5.7	147.0	11.0	1	0.51	1	0.3	1	0.0	0	0.0	0
12	1300	975.5	14.9	93.0	3.5	159.0	11.0	1	0.25	1	0.3	1	0.0	0	0.0	0
12	1400	974.8	16.7	94.0	2.7	152.0	4.0	9	1.02	1	1.0	1	0.0	0	0.0	0
12	1500	974.5	17.0	95.0	1.7	174.0	4.0	9	1.52	1	1.0	1	0.0	0	0.0	0
12	1600	974.3	14.8	94.0	2.7	170.0	11.0	1	1.27	1	0.8	1	0.0	0	0.0	0
12	1700	974.6	14.1	94.0	1.3	189.0	11.0	1	0.76	1	0.8	1	0.0	0	0.0	0
12	1800	974.7	16.0	95.0	0.7	358.0	11.0	1	1.78	1	0.8	1	0.0	0	0.0	0
12	1900	975.0	13.8	94.0	0.9	186.0	11.0	1	0.00	0	0.8	1	0.0	0	0.0	0
12	2000	975.4	12.7	93.0	1.9	143.0	13.0	1	0.00	0	0.5	1	0.0	0	0.0	0
12	2100	975.3	12.2	93.0	1.6	164.0	14.0	1	0.00	0	0.5	1	0.0	0	0.0	0
12	2200	975.4	11.1	92.0	1.8	143.0	18.0	1	0.00	0	0.3	1	0.0	0	0.0	0
12	2300	975.4	12.0	90.0	3.8	146.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0

Figure A-1. (Continued) (e.) 11 Jan 1990, (f.) 12 Jan 1990

(g.) Data File: *hl01390.met*

Fort Hunter-Liggett, CA 13 Jan 1990 Winter Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 1

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
13	000	975.0	11.9	90.0	3.1	152.0	24.0	1	0.00	0	0.0	0	0.0	0	0.0	0
13	100	974.4	11.8	91.0	2.1	141.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
13	200	973.8	14.7	95.0	2.7	96.0	24.0	1	0.25	1	1.0	1	0.0	0	0.0	0
13	300	973.5	12.4	95.0	6.3	159.0	24.0	1	6.10	1	1.0	1	0.0	0	0.0	0
13	400	973.4	11.3	90.0	2.5	181.0	24.0	1	0.76	1	1.0	1	0.0	0	0.0	0
13	500	973.3	11.4	93.0	1.8	157.0	24.0	1	2.54	1	1.0	1	0.0	0	0.0	0
13	600	973.6	13.5	96.0	1.1	59.0	24.0	1	1.78	1	1.0	1	0.0	0	0.0	0
13	700	974.2	10.9	93.0	0.7	93.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
13	800	974.5	10.9	83.0	1.6	213.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
13	900	975.1	12.6	82.0	2.4	161.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
13	1000	975.6	13.0	82.0	3.4	147.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
13	1100	974.9	13.3	79.0	4.4	156.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
13	1200	973.7	12.6	75.0	2.2	177.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
13	1300	973.3	10.7	90.0	3.4	163.0	24.0	1	2.29	1	1.0	1	0.0	0	0.0	0
13	1400	972.6	11.3	90.0	3.5	178.0	24.0	1	0.76	1	1.0	1	0.0	0	0.0	0
13	1500	972.6	11.3	90.0	4.4	194.0	24.0	1	2.03	1	1.0	1	0.0	0	0.0	0
13	1600	973.2	11.2	84.0	2.8	222.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
13	1700	973.4	10.7	87.0	1.1	197.0	24.0	1	0.25	1	1.0	1	0.0	0	0.0	0
13	1800	973.7	10.6	83.0	2.2	170.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0
13	1900	974.6	10.1	90.0	2.0	313.0	24.0	1	0.76	1	1.0	1	0.0	0	0.0	0
13	2000	975.0	12.1	95.0	1.2	165.0	24.0	1	1.02	1	1.0	1	0.0	0	0.0	0
13	2100	975.8	11.6	96.0	1.1	113.0	24.0	1	0.25	1	1.0	1	0.0	0	0.0	0
13	2200	976.2	9.0	95.0	0.9	80.0	24.0	1	1.27	1	1.0	1	0.0	0	0.0	0
13	2300	976.1	11.8	96.0	1.8	113.0	24.0	1	0.00	0	1.0	1	0.0	0	0.0	0

Figure A-1. (Continued) (g.) 13 Jan 1990

(a.) Data File: *hl10188.met*

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Fort Hunter-Liggett, CA 10 Apr 1988 Spring Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1988  2
              Press   Temp    RH   Wd Spd Dirct   Vis  Aer  Precip        Cloud Data
Day Time      (mb)     (C)   (%)   (m/s)  (deg)  (km)   H  (mm/hr) P   Amt L Amt M Amt H
101  000     980.5     8.6  47.0     0.6  337.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101  100     980.3     8.3  48.0     0.6  344.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101  200     980.1     7.2  54.0     0.8  356.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101  300     979.4     6.8  60.0     0.7  332.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101  400     979.8     5.5  62.0     0.3  318.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101  500     979.9     5.2  66.0     0.6  999.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101  600     980.2     4.1  78.0     0.2  999.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101  700     980.8     9.3  65.0     0.2  999.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101  800     981.0    15.1  46.0     0.4   86.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101  900     981.1    19.3  35.0     0.7  197.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1000     978.1    24.7  19.0     0.7  236.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1100     980.7    26.4  12.0     1.7  114.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1200     980.1    27.8  12.0     2.8  111.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1300     979.4    29.8  11.0     1.2  233.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1400     978.7    31.1  10.0     1.1  144.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1500     978.0    30.5  10.0     1.9  247.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1600     978.1    29.7  11.0     3.2  229.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1700     978.0    28.5  11.0     1.6  246.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1800     977.9    27.1  12.0     0.8  190.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 1900     978.0    21.7  15.0     0.7  299.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 2000     978.7    16.3  24.0     1.5  313.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 2100     979.1    14.0  35.0     0.7  338.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 2200     979.0    13.1  35.0     1.0  302.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
101 2300     979.0    12.4  37.0     1.0  331.0  24.0   1    0.0    0   0.0 0 0.0 0 0.0 0
```

(b.) Data File: *hl10288.met*

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Fort Hunter-Liggett, CA 11 Apr 1988 Spring Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1988  2
              Press   Temp    RH   Wd Spd Dirct   Vis  Aer  Precip        Cloud Data
Day Time      (mb)     (C)   (%)   (m/s)  (deg)  (km)   H  (mm/hr) P   Amt L Amt M Amt H
102  0 0     978.8    11.0  39.0     0.8  334.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102  1 0     978.6     9.9  42.0     0.7  330.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102  2 0     978.2     8.1  48.0     0.6  321.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102  3 0     977.9     7.6  49.0     0.9   20.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102  4 0     977.6     6.7  57.0     0.4  339.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102  5 0     977.3     5.3  61.0     0.8  297.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102  6 0     977.8     3.8  73.0     0.9  303.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102  7 0     978.3     9.7  62.0     0.3  116.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102  8 0     978.2    14.7  43.0     0.5  278.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102  9 0     978.2    19.4  27.0     0.7  223.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102 10 0     977.8    24.2  16.0     0.6  145.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102 11 0     977.3    27.5  13.0     1.1  121.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102 12 0     976.4    28.8  12.0     2.2  114.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102 13 0     975.6    30.6  11.0     1.8  204.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102 14 0     975.2    30.3  10.0     3.5  208.0  24.0   1    0.00   0   0.3 2 0.0 0 0.0 0
102 15 0     974.8    29.3  11.0     3.4  221.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102 16 0     974.6    29.0  11.0     2.7  200.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102 17 0     974.4    28.1  11.0     2.0  186.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102 18 0     974.3    26.9  12.0     0.7  246.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102 19 0     974.7    20.2  16.0     0.6  999.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102 20 0     975.3    15.0  32.0     0.9  331.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102 21 0     975.9    12.1  37.0     0.8  326.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102 22 0     976.1    10.2  45.0     0.6  333.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
102 23 0     976.0     9.6  45.0     0.6  298.0  24.0   1    0.00   0   0.0 0 0.0 0 0.0 0
```

Figure A-2. Meteorological Data for Spring at Fort Hunter-Liggett, California, (a.) 10 April 1988, (b.) 11 April 1988,

(c.) Data File: *hl10388.met*

Fort Hunter-Liggett, CA 12 Apr 1988 Spring Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1988 2

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
103	000	976.1	8.1	48.0	0.8	306.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
103	100	976.1	6.9	58.0	0.8	323.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
103	200	975.4	5.8	63.0	0.7	116.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
103	300	975.1	4.7	70.0	0.9	324.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
103	400	975.0	4.0	72.0	0.8	313.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
103	500	975.0	2.4	81.0	0.5	317.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
103	600	975.4	2.7	83.0	0.6	309.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	700	975.9	6.8	77.0	0.6	301.0	24.0	1	0.0	0	1.0	2	0.0	0	0.0	0
103	800	976.3	11.3	54.0	0.4	312.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
103	900	976.5	14.1	44.0	1.0	190.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
103	1000	976.5	18.5	35.0	1.3	137.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
103	1100	976.3	19.2	30.0	1.9	156.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
103	1200	975.8	21.7	29.0	2.0	122.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	1300	975.2	23.9	17.0	2.0	152.0	24.0	1	0.0	0	1.0	2	0.0	0	0.0	0
103	1400	975.2	23.4	13.0	3.0	178.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	1500	974.7	24.5	13.0	1.9	143.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	1600	974.6	23.5	13.0	2.3	176.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	1700	974.4	23.0	13.0	2.8	167.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	1800	974.9	20.4	15.0	1.3	207.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	1900	975.2	17.4	18.0	1.4	132.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	2000	976.1	13.3	30.0	0.9	328.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	2100	976.6	11.5	35.0	0.6	999.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	2200	977.1	9.6	43.0	0.7	284.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
103	2300	977.3	8.4	51.0	0.9	306.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0

(d.) Data File: *hl10488.met*

Fort Hunter-Liggett, CA 13 Apr 1988 Spring Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1988 2

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
104	000	977.3	7.9	60.0	0.4	295.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
104	100	977.2	8.2	59.0	0.2	18.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
104	200	976.6	7.3	63.0	0.7	315.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
104	300	976.8	7.1	73.0	0.9	323.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
104	400	976.4	8.3	75.0	0.5	109.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
104	500	976.2	8.6	76.0	0.7	159.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
104	600	976.3	8.9	78.0	0.4	133.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
104	700	976.7	9.4	82.0	0.6	333.0	24.0	1	0.0	0	1.0	2	0.0	0	0.0	0
104	800	963.0	10.2	85.0	0.8	318.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
104	900	977.0	11.0	85.0	0.8	207.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
104	1000	976.8	12.5	83.0	0.9	182.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
104	1100	975.8	16.0	59.0	0.8	176.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
104	1200	975.0	18.4	48.0	1.4	181.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
104	1300	974.2	20.2	37.0	3.7	145.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
104	1400	974.1	20.5	35.0	3.7	214.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
104	1500	973.8	18.5	38.0	4.4	240.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
104	1600	973.8	18.2	41.0	3.6	241.0	24.0	1	0.0	0	0.0	2	0.0	0	0.0	0
104	1700	914.9	15.8	42.0	2.5	220.0	24.0	1	0.0	0	0.0	2	0.0	0	0.0	0
104	1800	973.5	13.8	50.0	2.3	220.0	24.0	1	0.0	0	0.0	2	0.0	0	0.0	0
104	1900	973.6	11.5	71.0	3.5	226.0	24.0	1	0.0	0	0.0	2	0.0	0	0.0	0
104	2000	973.7	11.0	73.0	2.4	255.0	24.0	1	0.0	0	0.0	2	0.0	0	0.0	0
104	2100	974.4	10.1	80.0	0.5	203.0	24.0	1	0.0	0	0.0	2	0.0	0	0.0	0
104	2200	974.4	10.1	79.0	0.5	286.0	24.0	1	0.0	0	0.0	2	0.0	0	0.0	0
104	2300	974.1	10.4	82.0	0.4	999.0	24.0	1	0.0	0	0.0	2	0.0	0	0.0	0

Figure A-2. (Continued) (c.) 12 April 1988, (d.) 13 April 1988,

(e.) Data File *hl10588.met*

Fort Hunter-Liggett, CA 14 Apr 1988 Spring Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1988 2

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
105	000	973.9	10.7	82.0	1.1	141.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
105	100	973.2	10.1	84.0	0.7	132.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
105	200	972.4	10.4	85.0	1.0	137.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
105	300	972.0	10.4	86.0	1.4	136.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
105	400	969.0	10.2	90.0	2.0	122.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
105	500	970.8	10.1	91.0	2.2	121.0	16.0	1	0.0	0	0.3	2	0.0	0	0.0	0
105	600	971.0	10.2	92.0	1.6	107.0	11.2	1	0.0	0	0.8	2	0.0	0	0.0	0
105	700	971.4	10.1	92.0	1.1	124.0	11.2	1	0.0	0	1.0	2	0.0	0	0.0	0
105	800	971.7	9.8	88.0	0.8	136.0	24.0	1	0.0	0	1.0	2	0.0	0	0.0	0
105	900	972.2	9.8	88.0	1.5	133.0	16.0	1	0.0	0	1.0	2	0.0	0	0.0	0
105	1000	972.4	9.8	88.0	1.3	133.0	16.0	1	0.0	0	1.0	2	0.0	0	0.0	0
105	1100	971.8	12.7	80.0	1.0	116.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	1200	971.3	12.5	82.0	2.9	90.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	1300	971.0	13.6	70.0	3.8	129.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	1400	970.5	15.4	49.0	2.6	161.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	1500	969.9	14.5	47.0	3.3	160.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	1600	970.4	14.2	49.0	1.5	207.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	1700	971.1	11.7	63.0	2.2	329.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	1800	971.9	9.8	77.0	2.2	30.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	1900	972.5	9.2	88.0	2.3	22.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	2000	973.3	9.1	90.0	0.4	103.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	2100	973.5	9.3	91.0	0.8	307.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	2200	973.9	9.3	91.0	0.3	335.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
105	2300	974.2	9.1	91.0	0.5	128.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0

(f.) Data File: *hl10688.met*

Fort Hunter-Liggett, CA 15 Apr 1988 Spring Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1988 2

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
106	000	974.2	8.8	91.0	0.5	0.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	100	974.0	7.7	92.0	0.5	359.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	200	973.9	7.1	93.0	0.5	317.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	300	974.1	7.2	92.0	1.3	306.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	400	974.5	7.0	93.0	0.7	120.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	500	974.4	7.4	93.0	0.3	289.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	600	974.4	7.8	92.0	0.7	294.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
106	700	975.3	8.5	92.0	0.6	118.0	24.0	1	0.0	0	1.0	2	0.0	0	0.0	0
106	800	975.6	8.9	91.0	0.8	102.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
106	900	975.8	9.4	89.0	0.7	312.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
106	1000	976.3	10.2	88.0	1.0	171.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
106	1100	976.7	10.6	86.0	1.8	115.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
106	1200	976.9	11.6	84.0	1.7	117.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
106	1300	976.8	12.5	82.0	1.1	116.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
106	1400	977.0	11.9	83.0	2.3	240.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	1500	976.9	12.1	83.0	1.1	250.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	1600	976.6	13.1	81.0	1.0	300.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	1700	976.5	13.2	81.0	0.4	320.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	1800	976.9	12.9	81.0	0.9	229.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
106	1900	977.0	11.4	84.0	1.1	231.0	24.0	1	0.0	0	0.5	2	0.0	0	0.0	0
106	2000	977.6	11.3	86.0	0.4	202.0	24.0	1	0.0	0	0.5	2	0.0	0	0.0	0
106	2100	977.9	11.2	88.0	0.6	92.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
106	2200	978.1	10.9	89.0	0.5	209.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
106	2300	978.1	10.7	90.0	1.1	35.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0

Figure A-2. (Continued) (e.) 14 April 1988, (f.) 15 April 1988,

(g.) Data File: *hl10788.met*

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Fort Hunter-Liggett, CA 16 Apr 1988 Spring Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1988  2
           Press   Temp   RH   Wd Spd Dirct  Vis   Aer  Precip       Cloud Data
Day Time   (mb)    (C)   (%)   (m/s)  (deg) (km)    H (mm/hr) P   Amt L Amt M Amt H
107  000  978.2   10.5  91.0    1.8    46.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107  100  978.4   10.2  91.0    0.3   350.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107  200  978.2   10.1  91.0    1.2    59.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107  300  978.3   10.3  91.0    1.0   273.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107  400  978.2   10.4  91.0    1.0   106.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107  500  978.6    9.7  90.0    1.5    63.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107  600  978.8    9.8  90.0    0.5   301.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107  700  979.8   10.0  90.0    1.0   159.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107  800  979.9   10.0  89.0    1.4    46.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107  900  980.3   10.4  88.0    0.6    55.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1000  980.7   11.1  87.0    0.8    76.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1100  980.7   11.5  86.0    0.8   167.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1200  980.5   12.1  84.0    0.8    14.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1300  980.3   12.6  82.0    1.3    52.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1400  980.1   14.4  76.0    1.1   355.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1500  979.9   14.3  75.0    1.2   359.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1600  980.0   13.4  77.0    2.2    21.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1700  980.2   13.1  80.0    2.5   317.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1800  980.3   12.7  82.0    1.0   317.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 1900  980.5   11.7  85.0    1.2    60.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 2000  981.2   10.9  87.0    1.8    43.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 2100  981.7   10.8  87.0    0.4   253.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 2200  982.0   10.6  88.0    1.0    76.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
107 2300  982.0   10.5  89.0    0.3     5.0 24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
```

Figure A-2. (Continued) (g.) 16 April 1988

(a.) Data File: *hl19789.met*

Fort Hunter-Liggett, CA 16 Jul 1989 Summer Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1989 3

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
197	000	981.0	11.4	38.0	0.6	300.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	100	980.9	10.4	42.0	0.9	307.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	200	981.0	9.1	43.0	0.5	285.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	300	981.3	8.3	45.0	0.6	318.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	400	981.3	8.1	45.0	0.3	329.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	500	981.6	7.7	48.0	0.9	317.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	600	982.2	9.1	47.0	0.7	304.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	700	982.6	15.0	39.0	0.8	136.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	800	982.9	18.3	39.0	0.8	222.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	900	982.7	22.0	30.0	1.2	204.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1000	982.8	24.4	26.0	1.5	178.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1100	982.6	28.5	19.0	1.9	158.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1200	982.0	31.1	16.0	1.4	186.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1300	981.4	32.0	15.0	2.5	42.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1400	981.0	32.3	16.0	3.1	27.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1500	980.5	33.1	14.0	1.4	15.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1600	980.0	33.1	14.0	2.9	1.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1700	979.7	32.5	14.0	3.5	12.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1800	979.4	31.2	16.0	4.3	4.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	1900	979.7	29.5	18.0	1.6	340.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	2000	979.8	27.2	20.0	2.0	14.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	2100	980.3	26.2	23.0	2.8	6.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	2200	980.7	25.3	28.0	2.7	7.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
197	2300	980.7	21.4	33.0	0.6	191.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0

(b.) Data File: *hl19889.met*

Fort Hunter-Liggett, CA 17 Jul 1989 Summer Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1989 3

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
198	000	980.8	20.3	40.0	0.5	210.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	100	980.6	17.2	43.0	1.1	308.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	200	980.6	15.8	47.0	0.5	306.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	300	980.5	14.9	51.0	1.0	301.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	400	980.7	14.0	57.0	0.6	300.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	500	980.8	13.7	60.0	0.6	321.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	600	981.3	15.6	57.0	0.5	299.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	700	981.5	21.3	46.0	0.4	43.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	800	981.7	23.4	42.0	0.9	187.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	900	981.4	26.4	38.0	1.3	187.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1000	981.0	29.9	32.0	1.3	116.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1100	980.4	32.0	27.0	1.7	49.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1200	979.8	33.9	22.0	2.3	44.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1300	979.1	34.8	20.0	3.8	28.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1400	978.5	35.7	18.0	3.2	42.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1500	978.1	36.3	16.0	3.7	37.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1600	977.7	36.0	14.0	2.7	4.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1700	977.4	36.7	14.0	2.8	324.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1800	977.3	35.9	15.0	1.5	353.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	1900	977.7	33.2	18.0	2.0	330.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	2000	978.3	28.9	29.0	1.8	23.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	2100	979.0	27.0	33.0	0.9	44.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	2200	979.5	24.2	39.0	0.6	69.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
198	2300	979.5	22.1	41.0	0.5	292.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0

Figure A-3. Meteorological Data for Summer at Fort Hunter-Liggett, California, (a.) 16 July 1989, (b.) 17 July 1989,

(c.) Data File: *hl19989.met*

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Fort Hunter-Liggett, CA 18 Jul 1989 Summer Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1989  3
              Press   Temp    RH  Wd Spd Dirct   Vis   Aer  Precip        Cloud Data
Day Time      (mb)    (C)    (%)  (m/s)  (deg)  (km)    H (mm/hr) P   Amt L Amt M Amt H
199  000     979.8   20.3   46.0    0.6  329.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199  100     979.6   18.8   52.0    0.5  294.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199  200     979.6   17.6   57.0    0.5  316.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199  300     979.3   16.8   62.0    0.7  309.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199  400     979.2   16.0   66.0    0.3  353.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199  500     979.6   15.5   68.0    0.6  298.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199  600     979.9   17.0   65.0    0.7  314.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199  700     980.1   22.3   51.0    0.6  127.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199  800     980.2   26.0   42.0    0.4  175.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199  900     979.9   28.9   37.0    1.2  150.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1000     979.5   31.8   30.0    2.3  134.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1100     979.2   34.3   25.0    2.6   96.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1200     978.7   35.8   17.0    4.3   17.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1300     978.1   37.2   15.0    3.8   12.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1400     977.9   37.4   13.0    3.1   13.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1500     977.5   37.8   12.0    3.2   48.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1600     977.1   38.2   12.0    2.8   33.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1700     976.9   37.4   11.0    3.8   28.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1800     977.2   35.9   12.0    2.4  359.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 1900     977.7   32.9   14.0    2.6  359.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 2000     978.3   29.8   16.0    1.3    5.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 2100     979.2   26.4   21.0    0.6  151.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 2200     979.7   24.2   24.0    0.8  170.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
199 2300     979.8   22.0   28.0    0.8  999.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
```

(d.) Data File: *hl20089.met*

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Fort Hunter-Liggett, CA 19 Jul 1989 Summer Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1989  3
              Press   Temp    RH  Wd Spd Dirct   Vis   Aer  Precip        Cloud Data
Day Time      (mb)    (C)    (%)  (m/s)  (deg)  (km)    H (mm/hr) P   Amt L Amt M Amt H
200  000     979.7   19.7   36.0    0.4  288.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200  100     979.4   18.2   41.0    0.7  310.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200  200     979.3   16.7   44.0    0.6  346.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200  300     979.2   15.7   47.0    0.7  313.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200  400     979.1   15.1   47.0    1.0  311.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200  500     979.3   14.3   50.0    0.8  311.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200  600     979.8   16.2   46.0    0.9  302.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200  700     980.1   21.7   37.0    0.5  196.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200  800     980.0   24.8   33.0    0.8  189.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200  900     979.6   27.8   26.0    1.3  181.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200 1000     979.2   30.3   21.0    1.8  161.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200 1100     978.7   33.8   16.0    1.8  169.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200 1200     977.9   36.7   12.0    1.8   87.0  24.0    1   0.0    0   0.0 0 0.0 0 0.0 0
200 1300     977.3   37.6   10.0    3.6   47.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 1400     976.7   38.2    9.0    3.6   56.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 1500     975.9   38.4    9.0    3.6   54.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 1600     975.5   39.1    8.0    3.2   36.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 1700     975.3   38.2    9.0    3.5   42.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 1800     975.3   36.7    9.0    2.6  319.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 1900     975.7   34.1   10.0    3.0    6.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 2000     976.3   31.2   12.0    2.3  360.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 2100     977.1   27.1   18.0    0.9  227.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 2200     977.5   24.9   22.0    1.5  209.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
200 2300     977.7   22.7   26.0    0.5  190.0  24.0    1   0.0    0   0.3 2 0.0 0 0.0 0
```

Figure A-3. (Continued) (c.) 18 July 1989, (d.) 19 July 1989,

(e.) Data File *hl20189.met*

Fort Hunter-Liggett, CA 20 Jul 1989 Summer Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1989 3

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
201	000	977.4	19.6	30.0	0.8	335.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	100	977.3	17.6	37.0	0.5	308.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	200	977.2	16.4	40.0	0.8	304.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	300	977.2	15.4	44.0	0.5	14.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	400	977.4	14.6	46.0	0.6	284.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	500	977.7	13.6	48.0	0.3	268.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	600	977.9	14.7	48.0	0.7	309.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	700	977.8	20.3	40.0	0.5	308.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	800	977.7	25.2	31.0	0.7	156.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	900	977.6	27.4	26.0	1.7	120.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1000	977.5	29.6	22.0	1.2	202.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1100	976.9	33.6	14.0	2.5	125.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1200	976.3	35.6	12.0	2.2	75.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1300	975.5	37.9	10.0	2.2	141.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1400	974.7	38.6	8.0	3.6	49.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1500	974.0	38.9	8.0	3.6	51.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1600	973.2	38.4	8.0	4.0	36.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1700	972.9	37.2	8.0	4.3	42.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1800	972.9	34.7	9.0	3.8	37.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	1900	973.3	31.4	11.0	1.9	52.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	2000	973.8	27.1	13.0	1.6	32.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	2100	974.6	24.3	16.0	0.6	255.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	2200	975.0	21.9	19.0	0.4	80.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
201	2300	975.1	19.4	22.0	0.5	321.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0

(f.) Data File: *hl20289.met*

Fort Hunter-Liggett, CA 21 Jul 1989 Summer Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1989 3

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
202	000	975.1	17.2	28.0	0.7	311.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	100	[illegible]	15.7	34.0	0.5	316.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	200	[illegible]	14.8	36.0	0.5	300.0	24.0	1	0.0	0	0.5	2	0.0	0	0.0	0
202	300	974.8	13.3	39.0	0.8	295.0	24.0	1	0.0	0	0.5	2	0.0	0	0.0	0
202	400	974.9	13.6	41.0	0.7	109.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
202	500	975.2	12.2	44.0	0.5	318.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
202	600	975.6	14.3	42.0	0.3	999.0	24.0	1	0.0	0	0.8	2	0.0	0	0.0	0
202	700	976.0	18.8	39.0	0.7	162.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	800	976.2	21.3	38.0	1.3	141.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	900	975.9	24.6	31.0	1.1	170.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	1000	975.8	28.9	20.0	2.2	130.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	1100	975.5	31.7	15.0	3.3	140.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	1200	975.0	34.3	11.0	2.9	106.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	1300	974.5	36.2	9.0	2.9	101.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	1400	974.1	37.3	9.0	3.3	125.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	1500	973.7	37.0	9.0	3.8	157.0	24.0	1	0.0	0	0.3	2	0.0	0	0.0	0
202	1600	973.5	36.6	9.0	2.8	183.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
202	1700	973.4	35.0	10.0	3.9	162.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
202	1800	973.6	33.6	10.0	2.2	211.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
202	1900	974.1	31.3	11.0	2.5	160.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
202	2000	974.4	26.8	15.0	1.9	109.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
202	2100	975.0	23.5	18.0	0.7	288.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
202	2200	975.5	20.4	20.0	1.0	314.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
202	2300	975.9	18.3	28.0	0.5	312.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0

Figure A-3. (Continued) (e.) 20 July 1989, (f.) 21 July 1989,

(g.) Data File: *hl20389.met*

Fort Hunter-Liggett, CA 22 Jul 1989 Summer Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1989 3

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
203	000	976.0	16.7	35.0	0.6	312.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	100	975.9	15.0	38.0	0.5	305.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	200	975.9	13.6	41.0	0.5	300.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	300	976.0	12.8	42.0	1.1	302.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	400	976.2	13.1	42.0	0.4	305.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	500	976.4	13.0	42.0	0.3	350.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	600	976.8	13.5	43.0	0.6	318.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	700	977.3	17.1	39.0	0.8	311.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	800	977.6	23.5	29.0	1.4	305.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	900	977.5	27.0	27.0	1.2	7.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1000	977.5	30.0	23.0	1.3	181.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1100	977.5	31.1	16.0	4.3	156.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1200	977.4	33.1	12.0	4.8	146.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1300	977.4	32.9	12.0	3.3	174.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1400	977.3	33.6	12.0	3.2	185.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1500	977.1	33.4	12.0	3.7	171.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1600	977.1	33.2	12.0	2.8	189.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1700	977.1	32.8	12.0	2.4	190.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1800	977.2	31.4	13.0	2.5	210.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	1900	977.6	28.3	16.0	2.6	139.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	2000	978.2	25.1	21.0	1.4	96.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	2100	979.0	23.6	24.0	1.5	98.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	2200	979.2	21.6	28.0	0.6	297.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
203	2300	979.3	19.3	33.0	1.1	312.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0

Figure A-3. (Continued) (g.) 21 July 1989

(a.) Data File: *hl28790.met*

Fort Hunter-Liggett, CA 14 Oct 1990 Fall Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 4

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
287	000	976.9	8.9	37.0	0.8	310.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	100	977.1	8.4	36.0	1.1	314.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	200	977.0	8.1	39.0	0.4	24.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	300	976.8	7.0	38.0	1.0	299.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	400	976.9	6.7	36.0	0.5	999.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	500	977.1	6.4	39.0	0.4	154.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	600	977.3	5.0	40.0	0.6	316.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	700	977.7	7.6	38.0	0.4	999.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	800	978.0	13.6	28.0	0.3	999.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	900	978.1	16.9	22.0	0.9	167.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1000	977.9	22.0	16.0	0.8	137.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1100	977.4	24.8	15.0	1.6	151.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1200	976.4	27.6	13.0	1.4	192.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1300	975.4	29.5	12.0	2.2	52.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1400	974.9	30.6	11.0	1.8	62.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1500	974.6	30.9	11.0	2.5	47.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1600	974.5	29.7	11.0	2.6	40.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1700	974.6	27.6	12.0	2.2	45.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1800	974.9	23.5	14.0	0.6	238.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	1900	975.4	18.8	18.0	0.5	12.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	2000	975.8	15.7	20.0	0.6	299.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	2100	976.4	13.4	23.0	0.9	318.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	2200	976.6	11.7	28.0	1.0	316.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
287	2300	977.0	11.6	30.0	0.9	323.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0

(b.) Data File: *hl28890.met*

Fort Hunter-Liggett, CA 15 Oct 1990 Fall Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 4

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
288	000	977.0	10.3	34.0	0.7	338.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	100	977.4	10.1	33.0	0.6	317.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	200	977.1	9.4	36.0	0.3	347.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	300	977.0	8.1	41.0	0.5	17.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	400	977.2	6.9	44.0	0.4	320.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	500	977.3	5.6	46.0	0.6	318.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	600	977.5	5.1	47.0	0.6	290.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	700	978.0	7.2	46.0	0.5	140.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	800	978.4	13.3	37.0	0.6	107.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	900	978.4	17.0	32.0	1.8	147.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	1000	978.1	20.0	30.0	1.7	175.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
288	1100	977.7	23.1	21.0	1.6	179.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
288	1200	976.6	26.3	16.0	2.2	153.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
288	1300	975.8	28.0	15.0	2.1	71.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	1400	975.2	27.8	16.0	3.0	50.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	1500	974.6	28.5	15.0	2.9	62.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	1600	974.5	27.8	15.0	3.5	38.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	1700	974.5	25.9	17.0	2.4	49.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	1800	974.7	22.4	22.0	0.7	27.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	1900	975.5	18.4	29.0	0.6	270.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	2000	976.0	15.6	33.0	0.4	248.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	2100	976.6	13.5	40.0	0.4	287.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	2200	977.0	11.5	44.0	0.9	333.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
288	2300	977.3	11.2	48.0	1.1	310.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0

Figure A-4. Meteorological Data for Fall at Fort Hunter-Liggett, California, (a.) 14 October 1990, (b.) 15 October 1990,

(c.) Data File: *hl28990.met*

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Fort Hunter-Liggett, CA 16 Oct 1990  Fall Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990  4
              Press  Temp    RH   Wd Spd Dirct  Vis  Aer  Precip        Cloud Data
Day Time      (mb)    (C)   (%)   (m/s)  (deg) (km)   H (mm/hr) P   Amt L Amt M Amt H
289  000     977.5    9.9  50.0    0.6   322.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
289  100     977.4    9.5  51.0    1.1   304.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
289  200     977.0   10.8  50.0    0.9   308.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
289  300     976.8   11.4  49.0    0.6   307.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
289  400     976.5   11.9  48.0    0.7   291.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
289  500     976.7   10.6  51.0    0.5    13.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
289  600     977.0    9.7  55.0    0.7    13.0 24.0   1   0.0    0   0.5 1 0.0 0 0.0 0
289  700     977.0   10.3  53.0    0.9   294.0 24.0   1   0.0    0   0.5 1 0.0 0 0.0 0
289  800     977.5   13.2  53.0    1.0   308.0 24.0   1   0.0    0   0.5 1 0.0 0 0.0 0
289  900     977.7   16.0  54.0    0.6   251.0 24.0   1   0.0    0   0.5 1 0.0 0 0.0 0
289 1000     977.5   18.9  48.0    1.1   208.0 24.0   1   0.0    0   0.5 1 0.0 0 0.0 0
289 1100     976.9   21.1  41.0    1.3   191.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
289 1200     976.0   24.4  32.0    1.3    57.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 1300     975.1   25.8  25.0    1.3   310.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 1400     974.3   27.9  14.0    1.8   110.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 1500     974.2   27.7  13.0    2.5    18.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 1600     974.0   27.4  14.0    2.2    22.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 1700     973.9   26.8  13.0    1.9    15.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 1800     974.3   23.7  15.0    0.5   338.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 1900     975.1   19.5  19.0    0.5   275.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 2000     975.7   19.5  30.0    0.8   346.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 2100     976.4   17.8  35.0    0.6   357.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 2200     976.8   17.3  44.0    1.4   324.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
289 2300     977.0   14.1  44.0    0.8    53.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
```

(d.) Data File: *hl29090.met*

```
Fort Hunter-Liggett, CA 17 Oct 1990 Fall Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990  4
              Press  Temp    RH   Wd Spd Dirct  Vis  Aer  Precip        Cloud Data
Day Time      (mb)    (C)   (%)   (m/s)  (deg) (km)   H (mm/hr) P   Amt L Amt M Amt H
290  000     977.1   12.5  44.0    0.9   348.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290  100     977.2    9.7  50.0    0.5   308.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290  200     977.1    7.9  60.0    1.2     0.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290  300     977.0    7.4  57.0    0.8   276.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290  400     977.3    6.0  60.0    0.7   302.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290  500     977.9    6.1  63.0    0.9   338.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290  600     978.2    5.0  67.0    1.0   309.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290  700     978.8    6.2  57.0    0.9   298.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290  800     979.3   12.2  34.0    0.3    19.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290  900     979.4   17.3  20.0    0.4   245.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290 1000     979.1   22.6  14.0    1.0   160.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290 1100     978.8   24.8  13.0    2.4   141.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290 1200     978.3   26.3  12.0    2.4   147.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290 1300     977.7   28.0  11.0    1.5   151.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290 1400     977.2   29.1  11.0    2.1   111.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
290 1500     976.8   28.8  11.0    1.1   197.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
290 1600     976.6   27.5  12.0    2.0   141.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
290 1700     976.7   25.8  12.0    2.1    43.0 24.0   1   0.0    0   0.8 1 0.0 0 0.0 0
290 1800     977.2   23.6  14.0    0.7    85.0 24.0   1   0.0    0   0.5 1 0.0 0 0.0 0
290 1900     977.8   20.6  17.0    0.3   248.0 24.0   1   0.0    0   0.5 1 0.0 0 0.0 0
290 2000     978.1   18.0  20.0    0.8   326.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290 2100     978.4   16.0  22.0    0.6   309.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290 2200     978.7   14.1  25.0    0.3    89.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
290 2300     979.1   13.2  29.0    0.4   324.0 24.0   1   0.0    0   0.3 1 0.0 0 0.0 0
```

Figure A-4. (Continued) (c.) 16 October 1990, (d.) 17 October 1990,

(e.) Data File *hl29190.met*

Fort Hunter-Liggett, CA 18 Oct 1990 Fall Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 4

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
291	000	979.2	12.5	30.0	0.7	264.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	100	979.5	11.8	34.0	0.5	340.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	200	979.4	11.4	36.0	0.5	349.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	300	979.2	11.7	37.0	0.3	34.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	400	979.3	11.5	37.0	0.6	296.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	500	979.5	11.8	39.0	0.3	352.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	600	979.4	11.7	50.0	1.7	241.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	700	979.6	11.7	62.0	0.8	302.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
291	800	980.2	13.2	59.0	0.2	88.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
291	900	980.5	15.8	52.0	1.1	185.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
291	1000	980.3	18.5	44.0	0.6	188.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
291	1100	980.1	22.1	37.0	0.8	184.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
291	1200	979.4	24.1	28.0	1.2	8.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	1300	978.1	25.2	23.0	2.8	88.0	24.0	1	0.0	0	0.8	1	0.0	0	0.0	0
291	1400	977.8	26.0	22.0	2.1	67.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	1500	978.0	25.4	24.0	1.9	219.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	1600	978.1	24.2	21.0	1.4	152.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	1700	977.9	21.8	20.0	1.6	38.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	1800	978.2	19.1	26.0	1.8	70.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	1900	978.0	17.4	28.0	1.0	145.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	2000	978.1	14.4	33.0	0.6	281.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	2100	978.6	12.1	41.0	0.8	312.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	2200	978.6	10.8	43.0	1.0	312.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
291	2300	978.4	9.3	48.0	0.8	331.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0

(f.) Data File: *hl29290.met*

Fort Hunter-Liggett, CA 19 Oct 1990 Fall Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 4

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
292	000	978.6	8.8	49.0	0.6	999.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	100	978.4	9.3	49.0	0.9	310.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	200	978.0	8.8	49.0	0.6	341.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	300	977.8	8.2	52.0	0.6	314.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	400	977.6	7.9	54.0	1.0	312.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	500	977.7	8.6	54.0	0.7	296.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	600	978.2	8.8	55.0	0.7	307.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	700	978.3	7.9	59.0	1.0	313.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	800	978.8	13.1	57.0	1.4	303.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	900	978.8	16.8	47.0	1.7	13.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	1000	978.7	17.9	39.0	3.2	28.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	1100	978.5	18.9	37.0	3.6	13.0	24.0	1	0.0	0	0.3	1	0.0	0	0.0	0
292	1200	978.0	19.6	34.0	4.3	27.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	1300	977.2	20.4	29.0	3.8	25.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	1400	976.8	21.0	23.0	4.0	3.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	1500	976.7	21.0	23.0	4.8	7.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	1600	976.5	21.3	20.0	2.5	349.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	1700	976.9	19.2	28.0	2.8	319.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	1800	977.5	17.4	37.0	4.3	358.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	1900	977.8	16.5	39.0	3.6	359.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	2000	978.5	15.8	38.0	2.1	359.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	2100	979.0	15.1	38.0	2.2	359.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	2200	979.6	12.2	43.0	0.8	105.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
292	2300	979.7	10.0	51.0	0.2	99.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0

Figure A-4. (Continued) (e.) 18 October 1990, (f.) 19 October 1990,

(g.) Data File: *hl29390.met*

Fort Hunter-Liggett, CA 20 Oct 1990 Fall Surface Weather Data
316.90 36.00 121.23 8
1.00 24 1990 4

Day	Time	Press (mb)	Temp (C)	RH (%)	Wd Spd (m/s)	Dirct (deg)	Vis (km)	Aer H	Precip (mm/hr)	P	Cloud Data Amt	L	Amt	M	Amt	H
293	000	980.0	8.4	54.0	1.2	328.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	100	980.4	6.6	60.0	0.7	100.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	200	980.4	6.2	61.0	0.5	999.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	300	980.5	4.7	65.0	1.0	309.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	400	980.8	5.0	67.0	0.8	325.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	500	981.0	4.1	67.0	0.8	312.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	600	981.4	3.5	69.0	0.8	305.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	700	981.9	5.3	66.0	0.9	312.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	800	982.2	10.0	47.0	1.3	327.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	900	982.7	15.5	31.0	0.6	217.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1000	982.4	17.6	26.0	2.6	147.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1100	981.8	21.4	17.0	2.4	161.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1200	981.2	23.7	13.0	2.1	75.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1300	980.5	24.7	12.0	3.1	30.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1400	980.1	24.8	12.0	4.0	50.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1500	979.9	25.0	12.0	3.5	31.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1600	979.7	24.8	12.0	3.1	17.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1700	979.9	23.7	13.0	1.8	3.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1800	980.6	19.7	14.0	1.1	3.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	1900	981.3	15.0	16.0	0.5	123.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	2000	981.6	12.2	18.0	0.8	15.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	2100	982.4	13.2	18.0	0.5	298.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	2200	982.8	10.4	20.0	0.8	247.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0
293	2300	982.9	10.4	20.0	1.0	359.0	24.0	1	0.0	0	0.0	0	0.0	0	0.0	0

Figure A-4. (Continued) (g.) 20 October 1990

Appendix B
Adding Data to the SWOE Database

The current databases required by the SWOE models have been organized in such a manner so that new data can be easily added. This appendix describes how to add new data to the database.

B.1 Adding Additional Locations

To add a new location, the user first needs to create a subdirectory for the data for the new location. This subdirectory should be created in the directory, */install_path/data*. For example, data for Hunter-Liggett has been placed in the subdirectory, */install_path/data/hldata*. The user then can place the available meteorological data in the new subdirectory, along with a Unique Surface Material Code (USMC) file called *usmc.inp*, which contains all the USMCs for the new location. The USMC file **must** be called *usmc.inp* as this is the filename used by the CIS. The user must then create a file called *daylist.dat* in the new subdirectory, which contains the list of Julian days for which meteorological data are currently available. This file is described in detail in the next section on adding meteorological data.

If there are trees at this new location, the user also needs to put a file containing the tree locations in the new subdirectory. This file is called *tsites.ll*. Each line of the file contains the information required to describe each tree; namely, the longitude, latitude, elevation, tree type, and orientation angle of the tree relative to North. An example of a tree site location file is shown in Figure B-1. The longitude and latitude in degrees are entered as real numbers. The negative number in the longitude signifies the western hemisphere. The altitude is entered as an integer in meters above sea level. The tree type can be either 't1' or 't2', designating one of the two tree types currently available. The orientation angle can be either 0°, 90°, 180°, or 270°. No other orientation angles are currently available.

The user then needs to edit the *location.dat* file found in the subdirectory, */install_path/data*. The first line of this file contains the total number of locations available. The name of each location is then listed with the subdirectory name containing the data for this location. An example of the *location.dat* file is shown in Figure B-2.

The user can edit the *location.dat* file using a standard text editor. Note that any changes made to this file affect all the users of the SWOE models. To add a location, the user adds one to the current total number of locations available, and enters this number on the first line in the file. The user then moves to the end

```
-121.249023 35.941624 396 t2   0
-121.250450 35.944202 397 t1  90
-121.249931 35.944134 399 t1 180
-121.251770 35.943394 392 t1 270
-121.252182 35.943047 395 t2   0
-121.249809 35.942093 409 t2  90
-121.250549 35.941906 414 t2 180
-121.249817 35.942841 414 t1 270
-121.253250 35.942036 395 t2   0
-121.252563 35.941853 401 t2  90
```

Figure B-1. Example of a *tsites.ll* File for Defining Tree Locations

```
1 = Total # of locations available
Hunter-Liggett    hldata
```

Figure B-2. Example of the *location.dat* File for Defining the Names of Locations for Which Data are Available and the Names of the Subdirectories Where the Data are Stored on the Host Computer

of the file and enters a one word description of the location and the name of the new subdirectory created above. This subdirectory should now contain all the data for the new location. For example, the second line in the *location.dat* file shown in Figure B-2 contains the name 'Hunter-Liggett' for the location description, and the subdirectory name, *hldata*. All of the meteorological data and USMC data for Hunter-Liggett has been placed in the subdirectory */install_path/data/hldata*. The user then saves the changes to the *location.dat* file and can run the CIS to perform calculations for this location.

B.2 Adding Meteorological Data to the Database

The meteorological databases have also been organized in such a manner so that new data can be easily added. This section describes how to add data for a specific Julian day. The user first changes directory to the subdirectory containing the data for the location being used. For example, if new meteorological data are available for Hunter-Liggett, the user would first change directory to the subdirectory, */install_path/data/hldata*. The user then copies the new meteorological data file to this subdirectory.

The user then needs to edit the file, *daylist.dat*, located in this subdirectory, in order to add the new Julian day to the database. The first line of this file contains the total number of Julian days available. Each Julian day is then listed with the calendar date when the data were taken, the season, and the name of the

meteorological data file. An example of a *daylist.dat* file is shown in Figure B-3. Each location has its own *daylist.dat* file found in the subdirectory for that location's data.

```
8 = Total # of days in this file
  7     01/07/90   Winter   h100790.met
  8     01/08/90   Winter   h100890.met
101     04/10/88   Spring   h110188.met
102     04/11/88   Spring   h110288.met
197     07/16/89   Summer   h119789.met
198     07/17/89   Summer   h119889.met
287     10/14/90   Fall     h128790.met
288     10/15/90   Fall     h128890.met
```

Figure B-3. Example of a *daylist.dat* File Listing the Days for Which Meteorological Data are Available at a Given Location

The user can edit the *daylist.dat* file using a standard text editor. Note that any changes made to this file affect all the users of the SWOE models. To add a Julian day, the user adds one to the current total number of days in the file, and enters this number on the first line in the file. The user then inserts one line containing the Julian day, calendar date, season, and the name of the meteorological data file for that day. This line can be inserted so that the Julian days appear in order in the file *daylist.dat*. The user then saves the changes to the *daylist.dat* file and can run the CIS to perform calculations for this Julian day.

Appendix C

Input Files for the SWOE Drivers

There are several input files, transparent to the user, that are used by the SWOE drivers. The typical user will only need to be concerned with the configuration files, defined in Sections 6.3.1 and 6.4.1, for defining the simulation conditions. The transparent input files are described here for reference only. These input files are listed in Table C-1. Again, it is stressed that most users will not have to create or edit these files.

Table C-1. Input Files for the SWOE Program Drivers

FILE	PROGRAM USED BY	DESCRIPTION
itm91.inp	ITM	Input file for the ITM code
tree91.inp	TREETHERM	Input file for the TREETHERM driver (*treedrv*)
cld91.inp	Cloud models	Input file for the cloud structures model (*cldscene*)
rad91.inp	Radiance code	Input file used for the radiance driver (*runrad91*)
render91.inp	Scene Render	Input file for the scene rendering code

C.1 Input File for the ITM Driver

The input file for the ITM program driver is called, *itm91.inp*, and is written by the CIS to the user's local directory. This file consists of five records. Table C-2 lists the input records contained in the file. An example *itm91.inp* file is shown in Figure C-1.

The first record in the control file is a descriptive header supplied by the user or the CIS to characterize the calculation. This header must be 72 characters or less. The second record is the directory pathname to the ITM executable file, *itm*. The third record contains the name and full pathname of the USMC file which defines a specific location. The fourth record contains the four character "root" filename which is used as the prefix to the output files produced by the ITM. The fifth and final record contains the Julian day, hour of the simulation and the name and full pathname of the meteorological data file. The Julian day can be any integer number between 1 and 365, and the simulation hour can be any integer between 0 and 23. This record is read in using the format (i5,i5,a).

Table C-2. Description of the Input Records in the Control File *itm91.inp*

RECORD	DESCRIPTION
1	Descriptive header (72 characters or less)
2	Directory pathname for the ITM executable code
3	Name and location of the file containing the unique surface material codes
4	Four character "root" filename to be used as the prefix for all the output files
5	The Julian day followed by the simulation hour and the name and location of the environmental data to be used for the SWOE ITM simulation [Format: (i5,i5,a)]

```
BTI/MSAT/SWOE Input File for Scene Simulation
/home/tosh/nlp790/swoe91/exe/
/home/tosh/nlp790/swoe91/data/hldata/usmc.inp
test
   11    12/home/tosh/nlp790/swoe91/data/hldata/hl01190.met
```

Figure C-1. Example of an *itm91.inp* Input File for the ITM Program Driver

C.2 Input File for the TREETHERM Driver

The input file for the TREETHERM program driver is called, *tree91.inp*, and is written by the CIS to the user's local directory. This file consists of nine records. Table C-3 lists the input records contained in the file. An example *tree91.inp* file is shown in Figure C-2.

The first record in the control file is the four character "root" filename which will be used as the prefix to the output files produced by TREETHERM. The second record is the directory pathname to the TREETHERM driver executable file, *treedrv*. The third record contains the directory pathname for the location of the tree input and tree property files, *hltree1.inp, hltree1.prp, hlleaf1.prp, etc.* The fourth record contains the name and full pathname of the meteorological data file. The fifth record contains the name and full pathname of the file containing the longwave fluxes and diffuse solar. This file is produced by the ITM and written to the same directory as the location of the meteorological data file. The sixth record contains the Julian day of the simulation. The Julian day can be any integer number between 1 and 365. The seventh record contains the number of unique trees. There are currently two unique tree types that have been provided with the TREETHERM model. When executed with the CIS, both tree types are used if the user includes trees in the scene. The eighth record contains the number of

Table C-3. Description of the Input Records in the Control File *tree91.inp*

RECORD	DESCRIPTION
1	Four character "root" filename to be used as the prefix for the output files
2	Directory pathname for the TREETHERM executable code
3	Directory pathname for the tree input and tree property files
4	Name and location of the environmental data file to be used for the TREETHERM simulation
5	Name and location of the file containing the upward longwave fluxes and diffuse solar
6	The Julian day of the simulation
7	The number of unique trees (currently = 2)
8	The number of orientations and the orientation angles in ascending order
9	The number of simulation times and the simulation times in ascending order

```
test
/home/tosh/nlp790/swoe91/exe
/home/tosh/nlp790/swoe91/data/tree
/home/tosh/nlp790/swoe91/data/hldata/hl01190.met
/home/tosh/nlp790/swoe91/data/hldata/hl01190.flx
11
2
4  0  90 180 270
1  12
```

Figure C-2. Example of a *tree91.inp* Input File for the TREETHERM Driver

tree orientations for each tree type and the orientation angles. The rotation angles are entered as integers in ascending order. The ninth and final record contains the number of simulation times and a list of these simulation hours. The simulation hours can be any integer between 0 and 23 and are entered in ascending order.

C.3 Input File for the Cloud Models

The input file for the cloud models is called, *cld91.inp*, and is written by the CIS to the user's local directory. This file consists of nine records. Table C-4 lists the input records contained in the file. An example *cld91.inp* file is shown in Figure C-3. Note that the cloud models only need to be run under certain conditions. The user can determine if the cloud models are necessary by examining the solar flux and cloud cover at the simulation day and time. The cloud models are only required

when the following two conditions are satisfied:

1. The full direct solar flux (*i.e.*, the direct sunshine on a sunlit surface) exceeds the average hourly diffuse portion of the solar flux
2. Partly cloudy conditions exist

Note that full direct solar fluxes can be found in the *.sol* file for the simulation day which is produced by the ITM code and placed in the directory with the meteorological data for that location. It follows from these conventions that the cloud models are not required at nightime or during overcast conditions.

Table C-4. Description of the Input Records in the Control File *cld91.inp*

RECORD	DESCRIPTION
1	Descriptive header (72 characters or less)
2	Name of the output file from the *cldscene* program (This file is used as input to the *cldshdow* program)
3	Name of the output file from the *cldshdow* program
4	Integer random number seed
5	The Julian day followed by the simulation hour
6	Maximum x, y and z for the *cldscene* program (Calculated internally if set to '0.00 0.00 0.00')
7	x, y and z resolutions (km) for the *cldscene* program (For Hunter-Liggett: 0.064 0.064 0.100)
8	x and y scene domains (km) for the *cldshdow* program (For Hunter-Liggett: 1.99 1.50)
9	x and y scene resolutions (km) for the *cldshdow* program (For Hunter-Liggett: 0.002 0.002)

```
Input file for the TASC Cloud Model
clouds.dat
cldshd.dat
1
102 12
0.00 0.00 0.00
0.064 0.064 0.100
1.99 1.50
0.002 0.002
```

Figure C-3. Example of a *cld91.inp* Input File for the Cloud Models

The first record in the control file is a descriptive header supplied by the user or the CIS to characterize the calculation. This header must be 72 characters or less. The second and third records are the names for the output files from

the *cldscene* and *cldshdow* programs, respectively. The fourth record contains an integer random number seed. This can be set to '1' initially. The fifth record contains the Julian day and the hour of the simulation. The Julian day can be any integer number between 1 and 365, and the simulation hour can be any integer between 0 and 23. The sixth record contains the maximum x, y and z values for the *cldscene* program. These values are currently calculated internally if set to '0'. The seventh record contains the x, y and z resolutions in kilometers for the *cldscene* program. For Hunter-Liggett, the x, y and z resolutions are 0.064, 0.064 and 0.1 km, respectively. The eighth record contains the x and y scene domains in kilometers for the *cldshdow* program. In general, these values can be extracted from the USMC file for the selected location. The x domain must be greater than zero and less than or equal to the maximum x entered in Record 6. The y domain must be greater than zero and less than or equal to the maximum y entered in Record 6. For Hunter-Liggett, the x and y domains are 1.99 and 1.5 km, respectively. The ninth and last record contains the x and y scene resolutions in kilometers for the *cldshdow* program. In general, these values can be extracted from the USMC file for the selected location. The x resolution must be greater than zero and less than or equal to the x domain entered in Record 8. The y resolution must be greater than zero and less than or equal to the y domain entered in Record 8. For Hunter-Liggett, the x and y scene resolutions both set to 0.002 km.

C.4 Input File for the Radiance Driver

The input file for the radiance program driver, *runrad91*, is called, *rad91.inp*, and is written by the CIS to the user's local directory. The *rad91.inp* input file changes depending on whether terrain radiances, tree radiances or target radiances are being calculated. Table C-5 lists the input records contained in the file. Examples of the three types of *rad91.inp* input files are shown in Figures C-4-C-6.

The first record in the control file is a descriptive header supplied by the user or the CIS to characterize the calculation. This header must be 72 characters or less. Each following record in the *rad91.inp* input file contains not only the parameters described below, but also a one line description of the parameter. The second record is the installation directory pathname where the SWOE software was installed. The third record contains the four character "root" filename which is used as the prefix to the output files produced by the radiance code. This "root" filename should be the same four character "root" filename used when calculating temperatures for the same simulation conditions. The fourth record contains the name of the environmental data file or MET file to be used in the radiance calculations. The fifth record contains the subdirectory name of the location directory. This directory contains the USMC file and MET data files for that specific location. For Hunter-

Liggett, this record is set to *hldata*. The sixth record contains the Julian day of the simulation. The Julian day can be any integer number between 1 and 365. The seventh and eighth records contain the calendar month and day, respectively. The ninth record contains the simulation hour. The simulation hour can be any integer between 0 and 23. The tenth and eleventh records contain the latitude and longitude viewing conditions. The latitude and longitude are entered in degrees, minutes, seconds and hemisphere. The degrees and minutes are entered as integers, seconds as a real number and the hemisphere as one character, either *N*, *S*, *E*, or *W*. The twelfth record contains the viewing altitude in meters above ground level. This altitude can be any real number between 0.0 and 30,000.0 meters. Records 13, 14 and 15 contain the yaw, pitch and roll in degrees, respectively. The sixteenth record contains the sensor bandpass. If the user wishes to use a tophat response, the start and stop wavelengths in microns are entered on this line. These wavelengths must be between 0.2 and 25.0 microns. For a user-defined sensor bandpass, the user enters '0.00 0.00' for the start and stop wavelengths in Record 16 and a filter name (up to 40 characters) in Record 17. This filter name is defined in the data file *filters.dat* located in the directory */install_path/data/radiance*. This file is described in more detail in the users manual for the radiance program. Briefly, for each user-defined filter, the file, *filters.dat*, contains the filter name which is entered in the configuration file, followed by the number of wavenumbers that define the filter and then the corresponding wavenumber and spectral response. Record 18 contains a flag indicating whether or not shading needs to taken into account during the radiance calculations. This flag is calculated internally by the CIS. The flag is set to '1' if the full direct solar flux (*i.e.*, the direct sunshine on a sunlit surface) exceeds the average hourly diffuse portion of the solar flux. Otherwise, the flag is set to '0'. Note that full direct solar fluxes can be found in the *.sol* file for the simulation day which is produced by the ITM code and placed in the directory with the MET data for that location. Record 19 contains a flag indicating the run type. The radiance code is called several time by the CIS, and this flag informs the radiance code driver which radiances to calculate. The run type flag is set to '0' to calculate terrain radiances for the USMCs for this location. It is set to '1' to calculate tree radiances. The radiance driver must be called once for each tree type. Finally, the run type flag is set to '2' to calculate target radiances. The radiance driver must be called once for each target in the scene. Record 19 is the last record in the file if the run type flag is set to '0' and terrain radiances are being calculated.

Table C-5. Description of the Input Records in the Control File *rad91.inp*

RECORD	DESCRIPTION
1	Descriptive header (72 characters or less)
2	Installation directory pathname where the SWOE models were installed
3	Four character "root" filename used when calculating temperatures; this "root" filename will also be used as the prefix for the output files produced by the radiance code
4	Name of the file containing the environmental data to be used for the radiance calculations
5	Subdirectory name where data has been placed for the simulation location; for Hunter-Liggett this name is *hldata*
6	Julian day of the simulation
7	Calendar month of the simulation
8	Calendar day of the simulation
9	Simulation hour
10	Latitude for the viewing conditions in degrees, minutes, seconds, and hemisphere
11	Longitude for the viewing conditions in degrees, minutes, seconds, and hemisphere
12	Altitude for the viewing conditions in meters above ground level
13	Yaw for the viewing conditions in degrees
14	Pitch for the viewing conditions in degrees
15	Roll for the viewing conditions in degrees
16	Start and stop wavelengths in microns for the sensor bandpass; if both set to 0 a filter name must be given in the next record
17	User-defined filter name (up to 40 characters); this filter must be defined in the *filters.dat* file located in the directory */install_path/data/radiance*
18	Flag indicating if shadowing needs to be computed; this flag is currently calculated internally by the CIS
19	Flag indicating the run type for this run of the radiance code: 0 = calculate terrain radiances, 1 = calculate tree radiances 2 = calculate target radiances
	(Continued on next page)

Table C-5. Description of the Input Records in the Control File *rad91.inp* (Cont'd)

RECORD	DESCRIPTION
The following records are included if the run type in Record 19 is equal to 1 (trees):	
20	Number of tree orientations
The following records are repeated for each orientation:	
21	Tree geometry file name; this is the echo output file from TREETHERM
22	Tree temperature file name; this is the main output file from TREETHERM
The following records are included if the run type in Record 19 is equal to 2 (targets):	
20	Name of the file containing the target wireframe
21	Name of the file containing the target temperatures
22	Name of the target thermal file
23	Target number (1 - 99)
24	Target heading in degrees (0.0° = N, 90.0° = E, 180.0° = S, 270.0° = W)
25	Target altitude in meters above ground level
26	Target latitude in degrees, minutes, seconds and hemisphere
27	Target longitude in degrees, minutes, seconds and hemisphere

If the tree radiances are being calculated (*i.e.*, a run type flag of '1'), Record 20 is set to the number of tree orientations. This number should be equivalent to the number of orientations in Record 8 of the TREETHERM input file, *tree91.inp*. Records 21 and 22 are then repeated for each orientation angle. Record 21 contains the tree geometry file name, which is the echo output file from TREETHERM. Record 22 contains the name of the tree temperature file, which is the main output file from TREETHERM. Only one tree type is included at a time in the *rad91.inp* input file. The radiance code must be called once for each tree type, and the names of the tree output files in the *rad91.inp* file must be changed accordingly.

If the target radiances are being calculated (*i.e.*, a run type flag of '2'), Record 20 is set to the name of the target wireframe file. Record 21 is set to the name of the target temperature file and Record 22 contains the target thermal filename. These three files must be located in the directory *install_path/data/target*. Record 23 contains the target number. The radiance driver must be called once for each target in the scene. The target number can be any integer between 1 and 99. Record 24 contains the target heading in degrees, with 0.0° equal to North, 90.0° equal to East, 180.0° equal to South and 270.0° equal to West. Record 25 contains the

```
Radiance Code Input File for Scene Simulation
/home/tosh/nlp790/swoe91/            Installation path
         test               Root filename for output files
    hl01190.met             MET filename
         hldata             Location directory
             11             Julian Day of the Simulation
             01             Month
             11             Day
             12             Simulation Hour
 35  0  0.00  N             Latitude: degrees, minutes, seconds, hemi
121  0  0.00  E             Longitude: degrees, minutes, seconds, hemi
      5000.0000             Altitude (meters)
         40.000             Yaw (degrees)
         30.000             Pitch (degrees)
          1.000             Roll (degrees)
   8.00   12.00             Lambda 1,  Lambda2
NONE                                                  Filter name
              0             ISHDW flag
              0             Run Type: 0=terrain, 1=tree, 2=target
```

Figure C-4. Example of a *rad91.inp* Input File for the Radiance Driver For Calculating Terrain Radiances

target altitude in meters above ground level. The altitude can be any real number between 0.0 and 30,000.0 meters. Records 26 and 27 contain the target latitude and longitude in degrees, minutes, seconds and hemisphere. The target latitude and longitude are entered in an identical format to the latitude and longitude for the viewing conditions in Records 10 and 11.

C.5 Input File for the Scene Rendering Driver

The input file for the scene rendering driver is called, *render91.inp*, and is written by the CIS to the user's local directory. Table C-6 lists the input records contained in the file. An example *render91.inp* file is shown in Figure C-7.

The first record in the control file is a descriptive header supplied by the user or the CIS to characterize the calculation. This header must be 72 characters or less. The second record is the installation directory pathname where the SWOE software was installed. The third record contains the four character "root" filename which will be used as the prefix to the output files produced by the scene rendering program. This filename should be identical to the four character "root" filename used when calculating temperatures and radiances for the same simulation conditions. The fourth record contains the subdirectory name of the location directory. This directory contains the USMC file and MET data files for that specific location. For Hunter-Liggett, this record is set to *hldata*. The fifth record contains the Julian day of the simulation. The Julian day can be any integer number between 1 and 365.

```
Radiance Code Input File for Scene Simulation
/home/tosh/nlp790/swoe91/              Installation path
         test             Root filename for output files
   h101190.met            MET filename
       hldata             Location directory
           11             Julian Day of the Simulation
           01             Month
           11             Day
           12             Simulation Hour
 35  0   0.00  N          Latitude: degrees, minutes, seconds, hemi
121  0   0.00  E          Longitude: degrees, minutes, seconds, hemi
    5000.0000             Altitude (meters)
       40.000             Yaw (degrees)
       30.000             Pitch (degrees)
        1.000             Roll (degrees)
  8.00   12.00            Lambda 1,  Lambda2
NONE                                           Filter name
            0             ISHDW flag
            1             Run Type: 0=terrain, 1=tree, 2=target
            4             Number of tree orientations
   etestt1.000            Tree geometry file name, Orientation #1
   otestt1.000            Tree temperature file name, Orientation #1
   etestt1.090            Tree geometry file name, Orientation #2
   otestt1.090            Tree temperature file name, Orientation #2
   etestt1.180            Tree geometry file name, Orientation #3
   otestt1.180            Tree temperature file name, Orientation #3
   etestt1.270            Tree geometry file name, Orientation #4
   otestt1.270            Tree temperature file name, Orientation #4
```

Figure C-5. Example of a *rad91.inp* Input File for the Radiance Driver For Calculating Tree Radiances

The sixth record contains the simulation hour. The simulation hour can be any integer between 0 and 23. The seventh and eighth records contain the latitude and longitude viewing conditions. The latitude and longitude are entered in degrees, minutes, seconds and hemisphere. The degrees and minutes are entered as integers, seconds as a real number and the hemisphere as one character, either *N, S, E* or *W*. The ninth record contains the viewing altitude in meters above ground level. This altitude can be any real number between 0.0 and 30,000.0 meters. Records 10, 11 and 12 contain the yaw, pitch and roll in degrees, respectively. Record 13 contains the name of the radiance output file for the terrain radiances. Record 14 contains a flag indicating if trees were included in the scene or not. This flag is set to '1' if trees are present in the scene or '0' if no trees are present. If trees are present, the name of the tree location data file must be entered in Record 15 of the *render91.inp* input file. This tree location data file is currently created internally by the CIS, and is called <root>*tree.dat.* The CIS reads in the tree location file, *tsites.ll,* from the location subdirectory and appends the prefix name of the radiance code output

```
Radiance Code Input File for Scene Simulation
/home/tosh/nlp790/swoe91/          Installation path
        test              Root filename for output files
   hl01190.met            MET filename
      hldata              Location directory
          11              Julian Day of the Simulation
          01              Month
          11              Day
          12              Simulation Hour
 35  0  0.00  N           Latitude: degrees, minutes, seconds, hemi
121  0  0.00  E           Longitude: degrees, minutes, seconds, hemi
     5000.0000            Altitude (meters)
        40.000            Yaw (degrees)
        30.000            Pitch (degrees)
         1.000            Roll (degrees)
  8.00   12.00            Lambda 1,  Lambda2
NONE                                           Filter name
           0              ISHDW flag
           2              Run Type: 0=terrain, 1=tree, 2=target
      tank.geo            Target wireframe filename
      tank.tem            Target temperature filename
      tank.thm            Target thermal filename
           1              Target number
       45.00              Target heading (deg)
     10.0000              Target altitude (meters)
  0  0  0.00  N           Target Latitude: deg, min, sec, hemi
  0  0  0.00  W           Target Longitude: deg, min, sec, hemi
```

Figure C-6. Example of a *rad91.inp* Input File for the Radiance Driver For Calculating Target Radiances

file for each particular tree at the end of each line and writes each line to the file, <root>*tree.dat*. An example of a tree location data file modified for use with the scene rendering software is shown in Figure C-8. Record 16 contains the total number of targets in the scene. This is the last record in the file if there are no targets in the scene.

If there are targets in the scene, Records 17-22 are repeated for each target. Records 17 and 18 contain the names of the target polygon and vertex output files from the radiance calculations, respectively. Records 19-22 contain the target location. The user must enter the target heading, altitude, latitude and longitude.

Table C-6. Description of the Input Records in the Control File *render91.inp*

RECORD	DESCRIPTION
1	Descriptive header (72 characters or less)
2	Installation directory pathname where the SWOE models were installed
3	Four character "root" filename used when calculating temperatures and radiances; this "root" filename will be used as the prefix or the output files produced by the scene renderer
4	Location directory pathname where the data for the chosen location resides (For Hunter-Liggett this is: **data/hldata/**)
5	The Julian day of the simulation
6	The simulation hour
7	Latitude for the viewing conditions in degrees, minutes, seconds, and hemisphere
8	Longitude for the viewing conditions in degrees, minutes, seconds, and hemisphere
9	Altitude for the viewing conditions in meters above ground level
10	Yaw for the viewing conditions in degrees
11	Pitch for the viewing conditions in degrees
12	Roll for the viewing conditions in degrees
13	Name of the radiance output file for terrain radiance calculations
14	Trees present flag 1 = Trees present, 0 = NO Trees
15	Name of the tree location data file; This file is created internally by the CIS
16	Total number of targets in the scene
Records 17-22 are repeated for each target in the scene:	
17	Name of the target polygon output file from the radiance code
18	Name of the target vertex output file from the radiance code
19	Target heading in degrees (0.0° = N, 90.0° = E, 180.0° = S, 270.0° = W)
20	Target altitude in meters above ground level
21	Target latitude in degrees, minutes, seconds and hemisphere
22	Target longitude in degrees, minutes, seconds and hemisphere

```
BTI/MSAT/SWOE Input File for Scene Rendering
/home/tosh/nlp790/swoe91/            Installation path
          test            Root filename for output files
data/hldata/            Location directory path
            11            Julian Day of the Simulation
            12            Simulation Hour
 35  0  0.00  N           Latitude: degrees, minutes, seconds, hemi
121  0  0.00  W           Longitude: degrees, minutes, seconds, hemi
     5000.0000            Altitude (meters)
        40.000            Yaw (degrees)
        30.000            Pitch (degrees)
         1.000            Roll (degrees)
      test.bct            Radiance filename for Terrain Calculations
             1            1 = Trees present, 0 = NO Trees
  testtree.dat            Tree Location Data Filename
             2            Total Number of Targets
   testtg1.bcp            CIG polygon file for Target #1
   testtg1.bcv            CIG vertex file for Target #1
         45.00               Target heading (deg)
       10.0000               Target altitude (meters)
  0  0  0.00  N              Target Latitude: deg, min, sec, hemi
  0  0  0.00  W              Target Longitude: deg, min, sec, hemi
   testtg2.bcp            CIG polygon file for Target #2
   testtg2.bcv            CIG vertex file for Target #2
          0.00               Target heading (deg)
        2.0000               Target altitude (meters)
 60 15  0.00  N              Target Latitude: deg, min, sec, hemi
 90  0  0.00  E              Target Longitude: deg, min, sec, hemi
```

Figure C-7. Example of a *render91.inp* Input File for the Scene Rendering Driver

```
-121.249023 35.941624 396 t2   0 bmk2t200
-121.250450 35.944202 397 t1  90 bmk2t110
-121.249931 35.944134 399 t1 180 bmk2t120
-121.251770 35.943394 392 t1 270 bmk2t130
-121.252182 35.943047 395 t2   0 bmk2t200
-121.249809 35.942093 409 t2  90 bmk2t210
-121.250549 35.941906 414 t2 180 bmk2t220
-121.249817 35.942841 414 t1 270 bmk2t130
-121.253250 35.942036 395 t2   0 bmk2t200
-121.252563 35.941853 401 t2  90 bmk2t210
```

Figure C-8. Example of a <root>*tree.dat* File for Defining Tree Locations and Corresponding Radiance Output Filenames